STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

Bulletin No. 60

INTERIM REPORT TO THE
CALIFORNIA STATE LEGISLATURE
ON THE

SALINITY CONTROL BARRIER INVESTIGATION

GOODWIN J. KNIGHT
Governor

HARVEY O. BANKS
Director of Water Resources

March 1957

Robert Yelland Photograph

Typical Delta Channel

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

Bulletin No. 60

INTERIM REPORT TO THE
CALIFORNIA STATE LEGISLATURE
ON THE

SALINITY CONTROL BARRIER INVESTIGATION

Prepared Pursuant to
THE ABSHIRE-KELLY SALINITY CONTROL BARRIER ACT OF 1955
Chapter 1434, Statutes of 1955

GOODWIN J. KNIGHT
Governor

HARVEY O. BANKS
Director of Water Resources

March 1957

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HARVEY O. BANKS
DIRECTOR

GOODWIN J. KNIGHT
GOVERNOR

ADDRESS REPLY TO
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1120 N STREET GILBERT 2-4711

STATE OF CALIFORNIA
Department of Water Resources
SACRAMENTO

March 29, 1957

Honorable Goodwin J. Knight, Governor, and
Members of the Legislature of the
State of California

Gentlemen:

There is transmitted herewith Bulletin No. 60 of the Department of Water Resources, entitled "Interim Report to the California State Legislature on the Salinity Control Barrier Investigation". This is a report of the investigation conducted as authorized by Chapter 1434, Statutes of 1955, the Abshire-Kelly Salinity Control Barrier Act of 1955.

Bulletin No. 60 contains the conclusions which have been reached regarding the feasibility of alternative plans designed to (1) provide a means of transporting large quantities of water across the Sacramento-San Joaquin Delta, (2) repel salinity from the Delta channels, (3) improve the quality of water applied to Delta lands, (4) provide flood protection to Delta islands, and (5) include a means for delivering water from the Delta to the San Francisco Bay Area.

It is recommended that further studies of salinity control barriers be limited to the modified Junction Point Barrier Plan designated as the Biemond Plan, and that the North Bay Aqueduct unit of that plan be authorized. It is further recommended that funds be appropriated for acquisition of lands, easements, and rights of way, and preparation of plans and specifications for the North Bay Aqueduct, contingent upon reasonable assurance from the prospective water users of their willingness to assume the obligation for repayment of the reimbursable costs. It is further recommended that a policy relating to reimbursable and nonreimbursable costs be established by the Legislature.

Very truly yours,

Harvey O. Banks

HARVEY O. BANKS
Director

March 8, 1957

Mr. Harvey O. Banks, Director
State Department of Water Resources
P. O. Box 1079
Sacramento 5, California

Dear Sir:

1. In accordance with your request, the undersigned consultants have conferred with your staff on a number of occasions and reviewed the interim report to the California Legislature, entitled "Salinity Control Barrier Investigation." The detailed estimates and back-up data for this report have also been studied and taken into account in the following comments and recommendations.

2. It is our conclusion that the modified Biemond Plan described in the above-mentioned report is an essential feature of a coordinated California Water Plan. It appears to be entirely feasible, economical, and by far the best solution for conserving water and at the same time protecting the lower Delta lands from salt-water invasion. The master levee system and the Cross-Delta fresh water canal included in the Biemond Plan are urgently needed to prevent serious flooding of the many highly productive islands in the Delta. Although the full capacity of the Cross-Delta canal may not be needed for some years, it should be constructed soon as an integral part of the flood control plan.

3. We concur with the conclusion that the North Bay Aqueduct should be authorized and the studies for its design undertaken and completed as soon as possible. In the event that the project is authorized by the Legislature, we would urge that funds be provided to purchase key portions of the right-of-way required for the project before rapid, unplanned urban development jeopardizes or greatly increases the cost of the project.

4. The estimated cost of the work, as shown in the report, appears to be properly conservative and, with the contingencies which have been included, to be consistent with the preliminary status of the study. These estimated costs are based on the best available information on current prices. However, attention is called to the rising trend in construction costs, which may require an upward revision in the estimates when the project is authorized and designed, particularly for many portions of the plan which probably will not be placed under contract for two years or more.

5. In view of the superiority of the Biemond Plan over other alternatives, studies necessary for its final design should be continued to completion, to the end that its benefits in water conservation and flood protection may be enjoyed as soon as possible. We have made some specific recommendations regarding these studies directly to your staff.

6. We greatly appreciate the cooperation and assistance of your staff, which has supplied us with all the factual data we have requested.

Sincerely yours,

OJPorter

O. J. Porter

Ray K Linsley

Ray K. Linsley

ORGANIZATION

WATER PROJECT AUTHORITY OF THE STATE OF CALIFORNIA*

FRANK B. DURKEE, Director of Public Works
Chairman

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HARVEY O. BANKS, State Engineer
Executive Officer

ISABEL C. NESSLER
Acting Secretary

* The Salinity Control Barrier Investigation was initiated in July, 1955, under the jurisdiction of the Water Project Authority. With the abolishment of the Authority on July 5, 1956, the investigation became the responsibility of the Director of Water Resources.

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WILLIAM L. BERRY	Chief, Division of Resources Planning
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This investigation was conducted as a function of the California Aqueduct Section

ROBERT O. THOMAS	Chief, California Aqueduct Section

This report was prepared by, and the studies of the Salinity Control Barrier Investigation were under the direction of

HERBERT A. HOWLETT
Supervising Hydraulic Engineer

Whose principal assistants were

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and

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Assistance was furnished to the Salinity Control Barrier Unit by the following personnel from other functions of the Department of Water Resources

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UNIVERSITY OF CALIFORNIA

DR. HANS A. EINSTEIN .... Professor of Mechanical Engineering
DR. JAMES A. HARDER .... Assistant Research Engineer

BOARD OF CONSULTING ENGINEERS

The Director of Water Resources engaged a board of consulting engineers to review the work accomplished during the Salinity Control Barrier Investigation and to appraise the conclusions which were reached prior to this report. This reviewing board consisted of the following members:

HANS KRAMER,* Chairman
Brigadier General, Retired, U. S. Corps of Engineers
San Francisco, California

RAY K. LINSLEY
Professor of Civil Engineering
Stanford University
Stanford, California

O. J. PORTER
Porter, Urquhart, McCreary & O'Brien
Consulting Engineers
Newark, New Jersey

* General Kramer passed away on February 16, 1957. His keen interest in the Salinity Control Barrier Investigation resulted in many valuable contributions.

ACKNOWLEDGMENT

The contributions and assistance by many public and private agencies and individuals rendered to the Department of Water Resources during the investigation are gratefully acknowledged.

Special mention is made of the cooperation received from the United States Bureau of Reclamation, the United States Corps of Engineers, and the Reclamation Districts in the Sacramento-San Joaquin Delta.

CHAPTER I.

INTRODUCTION

The Central Valley of California is over 500 miles long and averages 120 miles in width. This valley is drained by the Sacramento River, which flows south, and by the San Joaquin River, which flows north. Near the mid-point of the State, these rivers join and discharge their flows into the chain of bays, Suisun, San Pablo and San Francisco, and finally to the Pacific Ocean.

At the confluence of the Sacramento and San Joaquin Rivers, an extensive delta has formed. This Delta is interlaced with some 500 miles of sloughs and channels separating over 50 islands which have been reclaimed for agricultural purposes during the last 100 years. During the winter months these channels must be capable of safely discharging some 600,000 second-feet of flood waters from the river systems; but during the summer months, the natural runoff of the river becomes insufficient to repel the tide-influenced salt water of the ocean from the Delta channels.

With the passage of time, California found it necessary to conserve large quantities of water in the Sacramento River Basin for transfer to the San Joaquin River Basin. As the Delta channels play an important role in this north-south transfer and about 500,000 acres are irrigated by diversions from these channels, it became necessary to maintain the quality of water in the Delta by wasting water into Suisun Bay specifically for salinity repulsion. With the ever-increasing demand for more and more water throughout California, consideration was given to every possible means of conserving the available supplies. One possible means of conserving water would be to construct physical works designed to separate the salt water of the Bay system from the fresh water of the river system and thereby recover the water now used for salinity repulsion.

Historically, the reclaimed tracts in the Delta have been extremely vulnerable to high water caused by floods, high tides, or a combination of both. ~~There~~ have ~~been 24 inundations since 1925, including the~~ flooding ~~of Empire Tract and Quimby Island during~~ December, 1955. At the present time, three major areas are under water. These are Lower Sherman Island, flooded since 1917, Porter Estate (Big Break), flooded since 1927, and Franks Tract, flooded since 1938.

The difficulty in maintaining adequate levees in the Delta results from the general occurrence of deep, intermixed, compressible peat upon which the existing levees have been constructed. In addition, the land surface of the islands in the central portion of the Delta is generally 10 feet or more below sea level, and as it continues to subside greater differences between water and land surfaces increase the forces on the levees. Overtopping of the levees has not been the primary cause of failures and subsequent inundation, since additional freeboard can be provided by emergency use of sandbags. Instead, sections of levees have been displaced inwardly to the island causing a major break which cannot be immediately repaired.

Numerous plans have been proposed for conserving a portion of fresh water which now flows unrestricted into Suisun Bay, and for providing flood protection to the Delta islands. As the result of an investigation completed in 1955, it was recommended that "further consideration be given only to proposals to construct closed barriers across the San Francisco Bay system at or upstream from the Chipps Island site," near Pittsburg.

The objective of the present investigation is to select and design a single plan which will (1) provide a means for transporting large quantities of water across the Delta without undue loss of water to Suisun Bay and without damage to Delta property owners, (2) repel salinity from Delta channels, (3) improve the quality of water applied to Delta lands, (4) provide a higher degree of flood protection to Delta islands, and (5) include a means of delivering water from the Delta to the San Francisco Bay Counties. The purpose of this interim report is to state the conclusions which have been reached regarding the feasibility of a Junction Point Barrier Plan or a Chipps Island Barrier Plan for these objectives. The need for certain modifications of both plans became apparent during this investigation. The modified version of the Junction Point Barrier Plan is referred to as the Biemond Plan. The Chipps Island Barrier Plan as revised is referred to as the Modified Chipps Island Barrier Plan.

AUTHORIZATION

The current investigation of salinity control barriers is a continuation of studies authorized by the Abshire-Kelly Salinity Control Barrier Act of 1953. It is, therefore, pertinent to briefly review the events which brought about the authorization for the additional study.

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The Abshire-Kelly Salinity Control Barrier Act of 1953 directed the Water Project Authority to study "the feasibility and economic value of construction by the State of a suitable barrier or barriers . . . at several alternate locations across San Francisco Bay, San Pablo Bay, Suisun Bay, and the Sacramento-San Joaquin Delta, for reclamation, for salinity and flood control purposes, and for the purpose of creating a supply of fresh water . . .". On March 30, 1955, the Water Project Authority transmitted a report to the Legislature entitled "Feasibility of Construction by the State of Barriers in the San Francisco Bay System," with a resolution recommending further investigation.

Abshire-Kelly Salinity Control Barrier Act of 1955

The resolution by the Water Project Authority and representations to the Legislature implemented the enactment by the Legislature of Chapter 1434, Statutes of 1955, the Abshire-Kelly Salinity Control Barrier Act of 1955, which states:

"*An act to provide for a study of the junction point barrier and appurtenant facilities, the Abshire-Kelly Salinity Control Barrier Act of 1955, relating to barriers for salinity and flood control purposes, declaring the urgency thereof, to take effect immediately.*

"*The people of the State of California do enact as follows:*

"SECTION 1. There is hereby appropriated to the Water Project Authority the sum of one hundred thousand dollars ($100,000), payable from the Flood Control Fund of 1946, to initiate the further investigation and study of the Junction Point Barrier and Chipps Island Barrier and appurtenant facilities, as such barriers and facilities are described in the report of the Water Project Authority to the Legislature entitled "Feasibility of Construction by the State of Barriers in the San Francisco Bay System," dated March, 1955, for the purposes of developing complete plans of the means of accomplishing delivery of fresh water to the San Francisco Bay area, including the Counties of Solano, Sonoma, Napa, Marin, Contra Costa, Alameda, Santa Clara, San Benito, and San Mateo, and the City and County of San Francisco, providing urgently needed flood protection to agricultural lands in the Sacramento-San Joaquin Delta, conducting subsurface exploration work in the delta and designing facilities appurtenant to the cross-delta aqueduct, obtaining more complete information on the hydrology of the delta, and studying integration of the proposed project in the California Water Plan.

"SEC. 2. The Water Project Authority may contract with such other public agencies, federal, state, or local, as it deems necessary for the rendition and affording of such services, facilities, studies, and reports to the Water Project Authority as will best assist it to carry out this act. The Water Project Authority may also employ, by contract or otherwise, such private consulting engineering and other technical services as it deems necessary for the rendition and affording of such services, facilities, studies, and reports as will best assist it to carry out this act.

"SEC. 3. It is the intent of the Legislature that in conducting the study and investigation the Water Project Authority shall confer and exchange information with and shall seek the participation of the United States Navy, the United States Bureau of Reclamation, the United States Corps of Engineers and the local port districts to the extent possible.

"SEC. 4. The Water Project Authority shall report to the Legislature the result of its study and investigation not later than March 30, 1957.

"SEC. 5. This act shall be known and may be cited as the Abshire-Kelly Salinity Control Barrier Act of 1955.

"SEC. 6. This act is an urgency measure necessary for the immediate preservation of the public peace, health or safety within the meaning of Article IV of the Constitution and shall go into immediate effect. The facts constituting such necessity are:

"The areas adjacent to the San Francisco Bay urgently need an adequate supply of fresh water for domestic and industrial uses. It is essential to the public health, safety and welfare that a study of salinity control barriers as a means of securing such a supply of fresh water, be undertaken without delay."

Agreement With Water Project Authority

To carry out the provisions of the Abshire-Kelly Salinity Control Barrier Act of 1955, The Water Project Authority executed a service agreement with the Division of Water Resources, Department of Public Works, on June 29, 1955, for performance of the required investigations and studies. On July 5, 1956, with the creation of the State Department of Water Resources, the Water Project Authority of the State of California and the Division of Water Resources of the Department of Public Works were each abolished. The functions of these two organizations became the responsibility of the newly created Department of Water Resources.

Budget Act of 1956

The $100,000 appropriation, provided by the Act of 1955 to initiate the further study of barriers, was supplemented by an appropriation of $200,000 for continuation of the studies during the 1956-57 fiscal year. This appropriation was provided by Chapter 1, Item 225, Budget Act of 1956.

The Abshire-Kelly Salinity Control Barrier Act of 1955 specified further investigation "of the Junction Point Barrier and Chipps Island Barrier and appurtenant facilities, as such barriers and facilities are described in the report . . . 'Feasibility of Construction by the State of Barriers in the San Francisco Bay System' ". In that report, both barrier plans included as one of their facilities, a South Bay Aqueduct to deliver water to Livermore Valley and the northern portion of Santa Clara County. A similar conveyance system, although following a slightly different alignment and providing wider service, received State authorization by Chapter 1441, Statutes of 1951, as a feature of the Feather River Project.

Item 419.5, Budget Act of 1956, provided $9,350,000 for studies of the Feather River Project. The item specified that of that amount, $3,550,000 " . . . shall be used only for engineering and exploration work, and for acquisition of reservoir sites for the Alameda-Contra Costa-Santa Clara-San Benito branch aqueduct in Alameda, Contra Costa, Santa Clara and San Benito Counties . . . ". That action, on the part of the Legislature, indicated that a *South Bay Aqueduct* would be constructed as a feature of the Feather River Project and, therefore, need not be considered as a feature of a barrier plan.

AREA OF INVESTIGATION

The area under study is that specified in the Abshire-Kelly Salinity Control Barrier Act of 1955 as the San Francisco Bay Counties and the Sacramento-San Joaquin Delta. The generalized limits of this area are shown on Plate 1, entitled "Area of Investigation."

San Francisco Bay Counties

The San Francisco Bay Counties, as defined by the Act, include Alameda, Contra Costa, Marin, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Solano and Sonoma. During the 50-year period of 1900-1950, the population of these 10 counties increased from about 664,700 to 2,695,700. More intensive agricultural use of the land also occurred during this period until, by 1950, over 300,000 acres of land were under irrigation. While these expansions were occurring, the average natural water supply, falling as precipitation on the watershed, remained constant. As the economic limits for developing the local runoff were reached, greater consideration was given to importing water from neighboring local areas and from more distant sources in the Central Valley and the North Coastal Areas. The complexity of importation systems can best be seen by studying the topography (see Plate 1) between fertile valleys of the San Francisco Bay Counties and water supplies in the Central Valley and North Coastal Areas. The Coast Ranges form a continuous barrier, except in the vicinity of Suisun Bay with most of the mountains attaining elevations of between 2,000 and 4,000 feet.

Future urbanization and irrigation calling for ever-increasing quantities of water, are expected on the gently sloping land and broad plains bordering San Francisco, San Pablo and Suisun Bays, in Livermore Valley, and in the highly valuable agricultural areas of Santa Clara and San Benito Counties. On the northern side of the bays, Marin County, Napa, Sonoma and Petaluma Valleys, together with the Santa Rosa Plain, appear to be the areas destined to absorb a large part of the expanding population of the San Francisco Bay Counties. While this urbanization is taking place, areas in Petaluma Valley, Sonoma Valley, Napa Valley and the Fairfield-Suisun marshlands are expected to be brought under irrigation.

Nearly all of the areas which now require water and are expected to demand more water as the result of future growth, are underlain by ground water basins. Those basins in the southern portion of Alameda County and in Santa Clara and San Benito Counties provide a measure of regulatory storage for runoff from tributary watersheds and produce sizeable quantities of water. However, the basins north of the bays provide relatively small quantities of storage and limited yields. Nearly every ground water basin in the San Francisco Bay Counties is overdrawn at the present time, and several are in danger of being impaired by sea water.

The people of the San Francisco Bay Counties are to be commended for their farsightedness in developing surface storage reservoirs to conserve portions of the available, and seasonally variable, local runoff. However, further opportunities for this type of development are limited and, in most cases, more costly per unit of water than import systems designed to carry larger quantities to benefit larger areas. The major import systems which have been constructed to obtain water from the Central Valley have provided the necessary water to permit extensive urban developments in the San Francisco Bay Counties.

Sacramento-San Joaquin Delta

The Sacramento-San Joaquin Delta lies in the Central Valley of California and embraces approximately 469,000 acres of land extending from Sacramento to about 10 miles south of Stockton. The Sacramento River with its tributary and overflow channels, flows into the northern portion of the Delta. The San Joaquin River enters the Delta from the south. The Mokelumne River with its tributaries (Cosumnes River and Dry Creek), and Calaveras River enter from the east. The confluence of the Sacramento and San Joaquin Rivers is near Antioch about 30 miles west of Stockton.

The many interconnected waterways of the Delta separate more than 50 islands ranging in size from a few to several thousand acres. The surfaces of a majority of these islands are at or below sea level and require high levees to prevent inundation during flood periods. Important navigation arteries for commercial craft including large ocean-going ships bound for the Port of Stockton, as well as recreational opportunities for boating, fishing and hunting are provided by the interconnecting waterways.

Ground water in the areas adjacent to the Delta is generally of excellent quality; however, the quality of ground water underlying the central portion of the Delta is poor. In some locations, a large body of trapped sea water reaches to within 50 feet of the land surface and when encountered by wells, will produce artesian flow.

The same channels which must carry some 600,000 second-feet of flood flows to the sea during the winter months, are open to sea-water intrusion during the summer months. Prior to the construction of the Central Valley Project, saline water from the ocean invaded the Delta channels and rendered the water therein unfit for agricultural use. In addition, poor quality irrigation return flows of the San Joaquin Valley enter the Delta through the San Joaquin River.

Intensive urbonization
Ookland Metropolitan Areo

Harvesting corn in the
Sacramento-San Joaquin
Delta

Robert Yelland Photograph

SCOPE AND CONDUCT OF INVESTIGATION

The objective of the investigation resulting from the Abshire-Kelly Salinity Control Barrier Act of 1953 was to weigh the relative merits of alternative barrier plans; the objective of the investigation directed by the Abshire-Kelly Salinity Control Barrier Act of 1955, is to choose between the Junction Point Barrier Plan (Biemond Plan) and Chipps Island Barrier Plan and design the most feasible plan. The current studies, therefore, require (1) refinements of the previous plans, cost estimates, and economic studies and (2) development of data for the design and construction of the selected plan.

The cost estimates and economic studies of the Junction Point and Chipps Island Barrier Plans, as described in the 1955 report were reviewed and the plans were modified as found necessary. The studies of future water requirements, previously prepared for the extremes of population, were re-evaluated to reflect the probable supplemental water requirements of the San Francisco Bay Area. A plan was then developed which could deliver sufficient water to keep pace with the demands.

A subsurface exploration program was initiated in the Delta to acquire information on (1) the depth of peat, and the nature and strength of the underlying stratum, and (2) the location, depth to, and thickness of the confining layer overlying the connate water which underlies portions of the Delta.

Hydrologic studies were made to determine the amount of fresh water needed to maintain the line of 1,000 parts of chlorides to 1,000,000 parts of water at various locations, under conditions which would exist with the Biemond Plan in operation.

An interagency committee, containing representatives of the United States Bureau of Reclamation, United States Corps of Engineers, University of California and the Department of Water Resources, was established to explore the use of an electronic analog as a tool in evaluating possible changes in Delta tidal characteristics which would result from construction of the Biemond Plan. At the recommendation of this committee, the construction and operation of an analog is being performed by the University of California at Berkeley under the direction of Dr. Hans A. Einstein.

A study was made to reappraise the economic value of a vehicular crossing at the Chipps Island barrier site. This study was made by the Division of Highways, Department of Public Works, under terms of a service agreement.

An experimental vertical baffle fishway was constructed to test its proficiency in passing anadromous fish, especially striped bass and shad. The structure was designed in accordance with general plans supplied by Department of Fish and Game officials, and is being operated jointly by the Departments of Fish and Game and Water Resources.

In January, 1957, a special board of consulting engineers was retained to review the progress of the investigation and to appraise the conclusions being formulated. This board consists of engineers having national recognition in the fields of foundations, flood control and hydrology.

CHAPTER II.

SALINITY CONTROL BARRIERS

The construction of a salinity control barrier would involve changes in many existing practices and might require changes in long-standing policies of public agencies. Recognizing these possibilities, the basic factors which are important to an understanding of salinity control are stated in the following section, prior to discussions of the Junction Point and Chipps Island Barrier Plans.

BASIC CONSIDERATIONS

Before one can understand the purpose of a salinity control barrier, he must have an appreciation of some of the factors which distinguish usable water from unusable water. A single set of rules cannot be established which can be applied to all circumstances. For example, an industrial plant may be able to use sea water for cooling purposes, and at the same time require distilled water for processing purposes. Drinking water should be clear, colorless, odorless, pleasant to the taste, free from toxic salts, and should not contain an excessive amount of dissolved mineral solids. As little as 0.5 part of boron to 1,000,000 parts of water may be lethal to some crops.

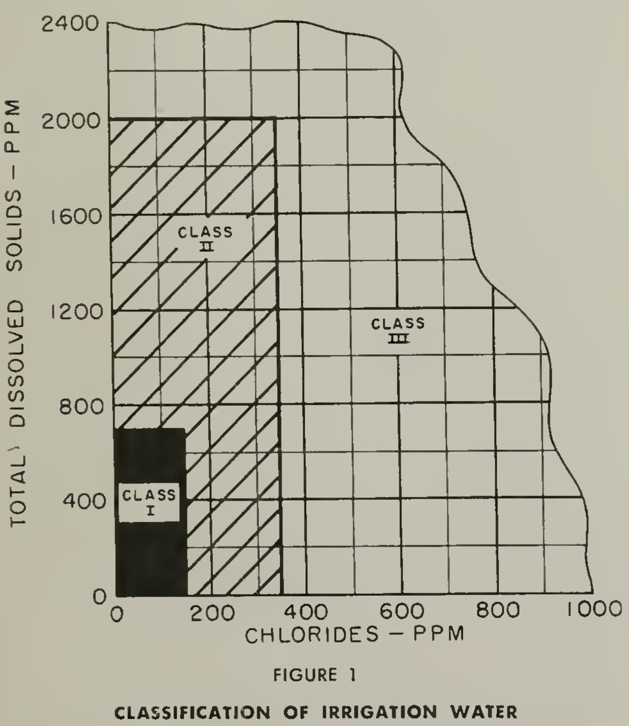

FIGURE 1

CLASSIFICATION OF IRRIGATION WATER

Class I—Excellent to Good
Class II—Good to Injurious
Class III—Injurious to Unsatisfactory

In this investigation the major consideration, quality-wise, is whether the water of the Sacramento-San Joaquin Delta is suitable for irrigation. The broad classifications of irrigation water set forth by Dr. L. D. Doneen of the Irrigation Division, University of California at Davis, are presented graphically in Figure 1. These classifications are not to be interpreted as rigid limits applicable to all conditions, but rather should be used as a generalized guide in understanding the problem at hand.

The intensive engineering studies of salinity problems in the Delta, conducted during the mid-twenties by the United States Bureau of Reclamation, the United States Corps of Engineers, the California Division of Water Resources, and the Sacramento Valley Development Association led to the generally accepted conclusion that the mean tidal cycle surface zone salinity should not exceed 1,000 parts of chlorides per 1,000,000 parts of water near Antioch. This criterion was selected to be assured of usable quality water in the Delta. The term mean tidal cycle refers to a 25-hour lunar day during which two high tides and two low tides would occur. The reference is to the mean location of the 1,000 part line during this 25-hour period; chlorides were measured from water samples taken from the river's surface. The exact location was specified to be at a point 0.6 mile below Antioch, as shown on Figure 2.

The view of the State of California in 1930 with respect to salinity control requirements was given in Bulletin No. 25 of the Department of Public Works, Division of Water Resources, entitled "State Water Plan." The following quotation is taken from that report:

> "In order to control the advance of salinity, a supply of water flowing into the delta must be provided sufficient in amount, first, to take care of the consumptive use in the delta and, second, an additional amount flowing into Suisun Bay sufficient to repel the effect on tidal action in advancing salinity. The studies show that the practicable degree of control by means of fresh water releases would be a control at Antioch sufficient to limit the increase of salinity at that point to a mean degree of not more than 100 parts of chlorine per 100,000 parts of water, with decreasing salinity upstream. In order to effect a positive control of salinity at Antioch to this desired degree, a flow of 3,300 second-feet in the combined channels of the Sacramento and San Joaquin rivers past Antioch into Suisun Bay would be required."

Subsequently, the Central Valley Project Act of 1933 was approved by a vote of the people of Cali-

fornia, which provided, among other things, for construction of:

". . . dam, reservoir and hydroelectric power plant . . . located on the Sacramento River, at or near Kennett, Shasta County, California . . . constructed and used primarily for improvement of navigation on the Sacramento River to Red Bluff, for increasing flood protection in the Sacramento Valley, for salinity control in the Sacramento-San Joaquin Delta, and for storage and stabilization of the water supply of the Sacramento River for irrigation and domestic use, and secondarily for the generation of electric energy and other beneficial uses."

The view of the Secretary of the Interior in 1947 with respect to salinity control functions of the Central Valley Project was presented in House of Representatives Document No. 146, 80th Congress, 1st Session as follows:

"13. The Central Valley Project, as authorized and at present partially constructed, will provide the following services when completed:

". . . (c) Salinity repulsion—The maintenance of a minimum flow of approximately 3,300 cubic feet per second at Antioch as proposed in operating schedules for Shasta (estimates range from 3,300 to 5,000 cubic feet per second, and no final figure is closely assured) is believed sufficient to prevent salinity intrusion in the Sacramento-San Joaquin Delta, thereby preventing such extensive crop damage as has been common in the recent past while at the same time permitting more beneficial use of lands in the affected area."

On June 18, 1951, the Bureau of Reclamation submitted supplements to its applications for water right permits to be used for purposes of the Central Valley Project as follows:

"In order to provide irrigation water of suitable quality for the Delta-Mendota and Contra Costa Canals, it is believed that up to 6,000 c.f.s. of direct diversion and/or storage releases may be required to flow into Suisun Bay in order to dispose of the chemical elements that would otherwise accumulate in the irrigation waters flowing in the Delta channels of the Sacramento-San Joaquin Rivers."

It may be seen that this statement does not mention control of salinity in the vicinity of Antioch. However, on the basis of House Document No. 146 and the aforementioned State bulletin and legislation, it may be seen that the Central Valley Project was originally considered to have as one of its objectives the maintenance of the line of 1,000 parts of chlorides to 1,000,000 parts of water at a point near Antioch.

The objective of the current study is to determine (1) the quantity of water which could be conserved from the amount required to control the mean tidal cycle line of salinity near Antioch by construction of either the Junction Point Barrier Plan or the Chipps Island Barrier Plan, and (2) to determine

FIGURE 2

LOCATION OF MEAN TIDAL CYCLE SURFACE ZONE SALINITY LINE OF 1,000 PARTS CHLORIDES TO 1,000,000 PARTS WATER UNDER PROJECT CONDITIONS.

which of the two plans would be most beneficial to the people of California. It is, therefore, necessary to state the conditions which are assumed to exist prior to changes which would result from construction of either of the plans. *The current study of salinity control barriers is based upon the premise that salinity is being controlled by the Central Valley Project at the point near Antioch shown in Figure 2, and that this is being accomplished by a minimum fresh water flow to Suisun Bay of 3,800 second-feet, consisting of 3,300 second-feet of surface inflow from the Sacramento and/or San Joaquin Rivers and 500 second-feet of accretion in the Delta.*

Sea water may be repelled from the Delta by two methods: (1) by maintaining a predetermined flow of fresh water from the Delta to Suisun Bay; or (2) by physical works constructed to separate the saline water of the bay system from the fresh water of the river system. At the present time salinity control is being achieved by maintaining a fresh water flow into Suisun Bay. However, this is at the cost of water sorely needed in other parts of California. Just as there are two methods of repelling salinity from the Delta, there are also two basic concepts for maintaining a satisfactory quality of water within the Delta: (1) by completely isolating the poor quality inflows from the high quality inflows, and (2) by diluting the poorer quality inflows with high quality inflows. The two barrier plans under consideration are illustrations of these two basic principals. Under the Biemond Plan, the isolation concept would be followed, while successful operation of the Chipps Island Plan would be dependent upon mixing of water in the barrier pool.

The flood stages in the Delta which cause levee failures generally result from flood flows of the Sacramento, Mokelumne and San Joaquin Rivers coupled with high tides, increased by offshore winds. It is difficult to maintain adequate levees in the Delta due to the general occurrence of deep, intermixed, compressible peat upon which the existing levees have been constructed. In addition, the land surface of the islands continues to subside resulting in greater differences between water and land surfaces. Historically and somewhat ironically, overtopping of the levees with inadequate freeboard has not been the prime cause of failures and subsequent inundation; instead, sections of levees have been displaced inwardly to the island causing a major break which cannot be immediately repaired to prevent complete inundation of the island.

This chapter discusses the relative merits of the Junction Point Barrier Plan and the Chipps Island Barrier Plan. A plan for providing flood protection to the Delta has been included in each barrier proposal. Studies disclosed the need for certain modifications of the original plans as described in the report entitled "Feasibility of Construction by the State of Barriers in the San Francisco Bay System," March, 1955. There follows a description of the physical features of the two plans, their costs, and their functional and economic feasibitities.

JUNCTION POINT BARRIER PLAN

The Junction Point Barrier Plan was designed in accordance with suggestions made by the Dutch engineer, Cornelus Biemond and is an example of the "control by isolation" principle. The Plan, as described in the 1955 report, would consist of control structures across the Sacramento River and Steamboat Slough, an isolated channel to convey fresh water across the Delta, a Delta Flood Control Plan, a North Bay Aqueduct and a South Bay Aqueduct. The location of the Delta features are shown on Plate 2 entitled "Junction Point Barrier and Delta Flood Control Plan."

The control structures would regulate the quantity of water passing into Suisun Bay from the Sacramento River and would provide a means of maintaining a desired water surface elevation in the river; the isolated Cross-Delta Canal would deliver water of high quality throughout the Delta and to the existing Central Valley Project Pumping Plant and the proposed Feather River Project Pumping Plant near Tracy; the proposed master flood control levees would provide much-needed flood protection to Delta lands; and, reduction of the tidal prism, accomplished by construction of the master flood control levee system, would result in conservation of a portion of the water now needed to maintain the line of 1,000 parts of chlorides to 1,000,000 parts of water at any given point.

As previously stated the current investigation has developed the need for certain modifications of the original Junction Point Barrier Plan. In order to distinguish between the original plan and the modification thereof, the original concept is called the Junction Point Barrier Plan while the modified version is referred to as the Biemond Plan.

Biemond Plan

The Biemond Plan reflects modifications to the Junction Point Barrier and Delta Flood Control Plan found desirable as the result of this investigation. While these modifications change the location of some of the principal structures, the basic concept is continued and functional feasibility improved. The locations of those elements of the plan within the Delta are shown on Plate 3 entitled "Biemond Plan."

Under the Junction Point Barrier Plan, provisions were not made for using San Joaquin River water during periods when it would be of satisfactory quality. Also, the entire flood flow of the San Joaquin River would have been restricted to a single Delta

Bouldin Island—Levee failure prevented by sandbags during flood of December, 1955

Bradford Island—Damage to levee along Fisherman Cut during high water of December, 1955

channel, which would have required expensive levee setbacks to provide the necessary channel capacity. Study disclosed that with the inclusion of a control structure at the junction of Paradise Cut with the San Joaquin River, the flood flows of the San Joaquin River could be accommodated within the existing levee system of the river, and in a channel through Paradise Cut, Grant Line Canal, Old River and Holland Cut. This latter route would also make it possible to utilize a portion of San Joaquin River flood flows at the Central Valley Project Pumping Plant and proposed Feather River Project Pumping Plant. The admission of flood flow into the Cross-Delta Canal at Paradise Cut necessitates a means of expelling the flows in excess of that pumped by the two plants, to the San Joaquin River. This would be accomplished by a control structure on Holland Cut between Holland Tract and Quimby Island. As Old River and Grant Line Canal are used extensively for commercial navigation purposes, a barge lock would be included at the Quimby Island end of this control structure.

Under the Junction Point Barrier Plan, Franks Tract, an inundated island near the center of the Delta, would have been reclaimed. In the reappraisal of that plan, it was found that several factors exist which require consideration in determining whether Franks Tract should be eliminated from the area under tidal influence. Among these factors are the value of the area for recreational uses, the proposed False River Cutoff feature of the Stockton Deep Water Channel (shown on Plate 3), and the effects of the tract on maintenance of the line of 1,000 parts of chlorides near Antioch. The economic value of these recreation and navigation considerations is not entirely subject to monetary appraisal. However, recognizing their importance, studies of the water conservation potential of the Biemond Plan were made with and without reclamation of Franks Tract. These studies disclosed that reclamation of Franks Tract would result in a substantial saving of fresh water; however, the saving could be accomplished at a future date when water might be considered more valuable than the other factors. For these reasons, it was concluded that Franks Tract should be left open to tidal influence, for the present.

The further review of the Junction Point Barrier Plan focused attention on the proposed flood channel of the Mokelumne River. This channel was originally designed to pass 25,000 second-feet to the San Joaquin River within a flood plane of 7.5 feet at Venice Island. Investigation disclosed that the channel could also serve as a portion of the Cross-Delta Canal, eliminating the cost of improving two separate reaches north of the San Joaquin River. Further study proved the superiority of using the South Fork of the Mokelumne River for this purpose, as (1) its alignment passes through areas having better foundation conditions, (2) it arrives at the San Joaquin River at a location which would not require a siphon of excessive length, (3) it would not require the Cross-Delta Canal to cross Bouldin, Venice or Mandeville Islands, and (4) it would not interfere with the present Stockton Deep Water Channel, nor would it require relocation or modification during construction of the proposed False River Cutoff.

With the decision to make dual use of the South Fork of the Mokelumne River, it became necessary to relocate the headworks of the Cross-Delta Canal. After considering several alternative sites, it was concluded that the best plan would be to enlarge the headworks of the Central Valley Project Delta Cross Channel at Walnut Grove. Thus under the Biemond Plan, a separate Cross-Delta Canal between Isleton and the San Joaquin River would be eliminated. However, the dual use of the South Fork of the Mokelumne River (to carry both flood flows to the San Joaquin River and fresh water to the pumps), would require a control structure at Little Venice Island. The structure would be used to discharge Mokelumne River flood flows during periods when the two major pumping plants would be supplied from the San Joaquin River. A vertical baffle fishway provided adjacent to this structure would permit upstream migration of anadromous fish, principally salmon and steelhead.

Under the Junction Point Barrier Plan, downstream migrating fish would have been screened from the Cross-Delta Canal near Isleton. However, under the Biemond Plan, either (1) the Sacramento, Mokelumne and San Joaquin River inlets to the Cross-Delta Canal would have to be screened, or (2) screens would be necessary at the intakes to the major pumping plants. As the Tracy Pumping Plant has recently been equipped with an elaborate screen, and as plans call for a similar device at the proposed Feather River Project Pumping Plant, the second alternative was adopted.

The decision to use the South Fork of the Mokelumne River for a portion of the isolated Cross-Delta Canal, and the conclusion that the most economic location for its headworks would be at Walnut Grove, made it possible to reconsider the location of the structures across Steamboat Slough and the Sacramento River. The factors involved in the selection of the sites relate to navigation and seepage. The principal use of the lock would be made by tugs towing oil barges to ports along the Sacramento River between the control structure and Sacramento, barges carrying farm produce from docks along the same reach to the ports of Stockton or Sacramento or to sugar refineries at Clarksburg and Tracy, and barges carrying material for levee improvements. If the control structure on Steamboat Slough were moved from its junction with Cache Slough to its junction with Sutter Slough, produce from Ryer and Grand Islands destined to downstream ports could be loaded at points along Steamboat Slough which would not require passing

the craft through a lock. Produce destined to upstream ports could be loaded on Miner, Sutter or Steamboat Sloughs and would likewise not require locking. However, a lock would still be required at the control structure across the Sacramento River.

The primary purpose of the structures across Steamboat Slough and the Sacramento River would be to control the amount of water passing into Suisun Bay and to maintain a desired water surface elevation at the intake to the Cross-Delta Canal. This desired elevation was computed to be five feet, mean sea level datum. The maintenance of this level, which is greater than the average tidal condition experienced at the present time, might cause seepage problems which could require remedial measures as a project cost. Therefore, the control structures should be as far upstream as possible. Having this in mind, a location was found near Ryde which would be suitable for the lock and control structure across the Sacramento River. At the proposed site, shown on Plate 3, a barge lock and vertical baffle fishway would be constructed.

Hydrologic studies disclosed that the line of 1,000 parts of chlorides per 1,000,000 parts of water could be maintained at Antioch under operation of the Biemond Plan and, therefore, the quality of water in the Sacramento River above the point would be essentially as exists today. Therefore, it would not be necessary to provide control structures (called for under the Junction Point Barrier Plan), across Cache and Lindsay Sloughs. This would also eliminate the need for a siphon under the Yolo By-Pass, and extensive channel improvements between the By-Pass and Lindsay Slough, originally proposed as features of the North Bay Aqueduct.

In summary, the principal modifications to the Junction Point Barrier and Delta Flood Control Plan were to make provisions for the Cross-Delta Canal to carry flood water during periods of excess runoff and to convey water from the Sacramento River to the major pumping plants during the summer months, thereby gaining greater control over the available water supply and eliminating unnecessary channels across valuable Delta land.

Description of Principal Structures. The general plan and type of structures proposed under the Biemond Plan are shown on Plate 4, "Layout of Principal Structures—Biemond Plan."

The control structures across the Sacramento River, Steamboat Slough, Holland Cut, and at Little Venice Island would be of similar design. The structures would have pile-supported, concrete sills, piers and abutments with fixed-wheel, vertical-lift, steel gates. The gate piers and abutments would support a hoist frame for raising the gates and two service bridges with 15-foot roadways. The hoist frames would extend about 170 feet out from an abutment into a storage and maintenance area where the gates could be serviced during periods of flood flows. The channels would be dredged to minus 20 feet and the levees riprapped for a distance of 500 feet upstream and downstream from the structures. Pertinent data on these structures are shown in Table 1.

TABLE 1

PERTINENT DATA ON CONTROL STRUCTURES OF THE BIEMOND PLAN

Location	Length, in feet	Gates		Sill elevation, in feet	Flood plane elevation, in feet
		Number	Size, in feet		
Sacramento River	410	5	55 x 23.5	—17	16.2
Steamboat Slough	470	6	55 x 23.5	—17	15.1
Little Venice Island	470	6	55 x 23.5	—17	7.5
Holland Cut	470	6	55 x 23.5	—17	7.5

A vertical baffle fishway would be constructed at the Ryde site with six baffles creating five bays each 15 feet wide by 20 feet long. The openings between the bays would be 3.67 feet wide extending for the full height of the baffles. A second fishway would be constructed on Little Venice Island with four baffles creating three 15 feet by 20 feet bays; the openings would be 3.17 feet wide. The minimum depth of water through both fishways would be 10 feet.

Barge locks would be constructed along the left bank of the Sacramento River and on Quimby Island adjacent to the Holland Cut control structure. These locks would be similar to the Calcasieu Lock on the Gulf Intercoastal Waterway near Lake Charles, Louisiana, as shown in an accompanying illustration. The sector gates and controls would be contained in pile-supported, concrete structures. The gate sills would be 12.0 feet and 13.0 feet below mean sea level at Sacramento River and Holland Cut sites, respectively. The riprapped levee sections, forming the lock chambers, would have a clear length of 600 feet and a bottom width of 56 feet. Timber pile guide walls would be provided along both sides of the chambers and in the approach channels.

The existing headworks of the Central Valley Project Delta Cross Channel at Walnut Grove would be modified to provide additional capacity. The existing structure has two radial gates 60 feet long by 30 feet deep. Two additional gates of the same dimensions would be constructed on the right or southerly end of the existing facility. The concrete structure would be pile-supported with a sill 15 feet below mean sea level. The highway bridge and the Southern Pacific Railroad bridge would each be lengthened by about 133 feet. The existing channel between the headworks and Snodgrass Slough would be adequate to convey the desired quantities of water.

The siphon under the Stockton Deep Water Channel would consist of four, 32-foot diameter, reinforced,

Calcasieu Lock on Gulf Intracoastal Waterway, near Lake Charles, Louisiana—Locks proposed at Ryde and Quimby Island would be of this type

U. S. Corps of Engineers Photograph

Drawbridge on Sacramento River near Freeport

Robert Yelland Photograph

concrete tubes. These tubes would be cast in sections in a graving dock, capped, floated to the site, and sunk onto circular caissons. The caissons would be 43 feet in diameter and 25 feet high, and would extend to 112 feet below mean sea level. The over-all length of the siphon would be 663 feet. Concrete pipe, 12 feet in diameter, would be placed vertically along the levees at both ends of the structure to provide a cellular-type cofferdam for levee stabilization.

The control structure at the head of Paradise Cut would be located on the left bank of the San Joaquin River and would consist of an ungated, broad-crested weir, 400 feet in length, with its crest five feet above mean sea level. To permit controlled diversion of good quality water into Paradise Cut during low stages on the San Joaquin River, gated inlets would be constructed at the right end of the weir. Three top-seal, radial gates 33.3 feet long and 10 feet high would control the flow. The gate sills would be five feet below mean sea level.

Cross-Delta Canal and Appurtenant Facilities. Under operation of the Biemond Plan, the Cross-Delta Canal would serve in a dual capacity, first to convey water from the Sacramento River to the major pumping plants near Tracy, and second to carry flood flows during periods of excessive runoff on the Mokelumne River and San Joaquin River. The basic criteria established for the design of this system of works, shown on Plate 3, were as follows:

1. The Cross-Delta Canal would be capable of conveying 4,600 second-feet of water to the Central Valley Project Pumping Plant near Tracy simultaneously with 11,000 second-feet of water to the proposed nearby Feather River Project Pumping Plant, plus water necessary for irrigation of the Delta, diversions to the Delta Uplands, and water developed by the Biemond Plan which would be diverted into San Joaquin Valley. A design capacity of 20,000 second-feet was selected.

2. The Cross-Delta Canal would deliver the water stated under condition 1 to the major pumping plants near Tracy at an elevation of mean sea level. It was assumed that under operation of the Biemond Plan, water in the Sacramento River would be held to a minimum elevation of five feet above mean sea level.

3. The reach of the Cross-Delta Canal carrying flood flows of the Mokelumne River would be capable of carrying 25,000 second-feet within a flood plane of 13.5 feet at New Hope Bridge and 7.5 feet at Little Venice Island.

4. The reach of the canal carrying flood flows of the San Joaquin River would be capable of carrying 35,000 second-feet within a flood plane of 22.0 feet at head of Paradise Cut and 7.5 feet at Holland Cut. Stages of intermediate points may exceed the existing flood planes, if provisions are included in the design to assure safety to the adjacent landowners.

Flood Control Features of Biemond Plan. The proposed Delta flood control features of the Biemond Plan were designed to provide the maximum degree of protection for the smallest capital investment, recognizing the significance of navigation and recreation, and to provide at project cost, facilities to maintain and improve upon the existing irrigation and drainage facilities. The plan developed to accomplish this objective was based upon principles used in Holland and set forth by Cornelus Biemond. Simply stated, the plan is to enclose groups of islands within a master levee system, thereby reducing the mileage of levees requiring reconstruction and annual maintenance against flood and tidal forces. The interior channels, severed during construction of the master levee system, could be maintained at nearly constant elevations and would serve to deliver water to and from the enclosed islands. The location of the proposed master levee system is shown on Plate 3.

Levees of the Sacramento River Flood Control Project now provide protection to most of the islands lying north of the Sacramento River and also to the northwestern sides of Sherman, Brannan, Andrus and Tyler Islands. Although under the plan there would be a slight increase in the flood plane on the Sacramento River and Steamboat Slough above their junction near Rio Vista due to severing Miner and Georgiana Sloughs, the existing levees are at satisfactory heights to contain the design flood flows. The Biemond Plan would not affect the flood planes on the Sacramento River below its junction with Steamboat Slough near Rio Vista. The Sacramento River Flood Control Project would continue to operate essentially as it does today. As previously described, the levees of the Cross-Delta Canal would be constructed to high standards and would carry the flood waters of the Mokelumne River, and a portion of the flood flows of the San Joaquin River, to the Stockton Deep Water Channel. Under the Biemond Plan the levees along the San Joaquin River from Paradise Cut to Stockton would not require reconstruction. The levees in this reach would be adequate, with bank protection, as in the federally-authorized Lower San Joaquin River Tributaries Project.

All channels entering the Stockton Deep Water Channel, excepting the main branch of the San Joaquin River, French Camp Slough, Calaveras River, Old River at Franks Tract and Threemile Slough would be severed. Bear Creek would be diverted into the Calaveras River. The total length of levee subjected to flood and tidal forces would be 450 miles. Of this total, 200 miles would be protected by the Sacramento River Flood Control Project, 58 miles would be in the Lower San Joaquin River Tributaries Project, and 192 miles would be levees not now under an authorized project.

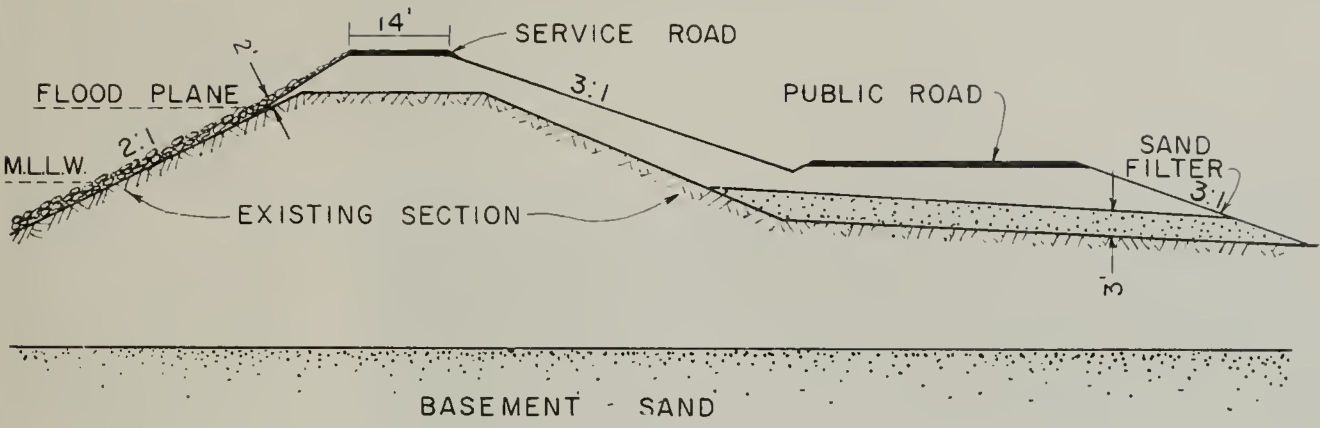

FIGURE 3

TYPICAL SECTION OF MASTER LEVEE

As a result of subsurface exploration, it appears unlikely that a single levee section can be adopted for all locations throughout the Delta. The type of levee section most adaptable to the foundation conditions existing at the construction site will be recommended at completion of the investigation. However, for estimating purposes, a section of the type and dimensions shown in Figure 3 was used.

This type of levee spreads the loads over a wide base, and results in a smaller concentrated load due to the relatively narrow crown. The use of the berm as a counterweight and as a road increases the factor of safety against foundation slipout failures, and reduces seepage through the levee.

Many of the channels which would be closed by the master levee system are navigable for fishing and recreational craft, and some are used for commercial tug and barge operations. Provisions were made to accommodate the commercial traffic by installation of locks at critical points. The Corps of Engineers was asked to analyze the effect of the levee system on recreational boating and to recommend solutions to the problems which it would create. The Corps of Engineers will undertake this study during 1957. Since the results are presently not available, it was assumed that three pleasure craft locks would be required at various but unspecified locations in the Delta.

While construction of the proposed master levee system would result in flood control and water quality benefits in the Delta, it would necessitate certain modifications of existing irrigation and drainage facilities. These modifications would be carried as project costs, but would have to be acceptable, both in design and operation, to the landowners. Studies of this subject have progressed only to a point from which preliminary estimates of cost could be obtained.

North Bay Aqueduct. A North Bay Aqueduct was originally conceived as a means of providing service from upstream barrier plans similar to that which could be provided by barrier plans which would create fresh water lakes in Suisun and San Pablo Bays. The system was designed to deliver supplemental water, needed during the 1960-2010 period, to the Fairfield-Suisun marshlands, Napa, Sonoma and Petaluma Valleys, and to the portion of Marin County draining to San Pablo Bay. A North Bay Aqueduct was shown to be economically justified and financially feasible in the March, 1955, report. Further investigation of this system of works was made to improve upon the location of the original alignment and to refine estimates of its cost. The estimate of probable water demands within the potential service area are described in Chapter III and a plan and profile of the North Bay Aqueduct is shown on Plate 5, "North Bay Aqueduct."

The modified North Bay Aqueduct was designed to be capable of delivering sufficient water to its proposed service area to meet the demands during the maximum month in year 2010. An allowance of 10 per cent was made in carrying capacities to provide for operational losses. The system was planned as a trunk facility, with daily fluctuations to be absorbed within the distributing agencies' systems. Only raw (untreated) water would be carried in the aqueduct; treatment, where required, would be furnished by the distributor.

Having established the basic policy of maintaining the line of 1,000 parts of chlorides near Antioch, and having demonstrated the ability of the Biemond Plan to accomplish that objective, it then became possible to modify the original North Bay Aqueduct and reduce its costs. With high quality water assured in the lower reaches of the Yolo By-Pass, it would not be necessary to provide an isolated system to transport water from Miner Slough to the Calhoun Cut Pumping Plant. Therefore, under the Biemond Plan, the aqueduct would divert water directly from Lindsay Slough through an improved channel following

Irrigable land in the Fairfield-
Suisun marshlands which could
be irrigated from the
North Bay Aqueduct

City of Santa Rosa

California State Chamber of Commerce Photograph

the existing alignment of Calhoun Cut. A louver-type fish screen would be constructed in Calhoun Cut to screen fingerling fish out of the system.

A pumping plant with a capacity of 900 second-feet would be constructed at the westerly end of Calhoun Cut. Water would be lifted at this point to elevation 15 feet and discharged into an unlined canal which would continue generally westward, crossing State Highway 12 about one-half mile northwest of Denverton. Water for use in portions of the Suisun marshlands and in the Collinsville area would be released from the aqueduct in this vicinity, and its capacity would be reduced to 680 second-feet. The elevation of the hydraulic grade line at the highway crossing would be about 13 feet.

The North Bay Aqueduct would continue westward in an unlined canal, lying generally parallel to and about one mile south of the highway, and passing about midway between the Potrero Hills and Travis Air Force Base. The aqueduct would reach navigable Suisun Slough at a point about one mile south of Suisun City. The water would be at elevation eight feet at its entrance to a siphon laid under this channel. The inverted siphon would be 12 feet in diameter and 600 feet in length.

The aqueduct would continue generally westward from Suisun Slough along the northerly fringe of the marshlands as an unlined canal having a capacity of 680 second-feet. Water would arrive at the town of Cordelia at an elevation of about three feet. The unlined portion of the North Bay Aqueduct would terminate at a pumping plant located about two miles northwest of Cordelia. The water would be at sufficient elevation, between the Calhoun Cut Pumping Plant and the Cordelia Pumping Plant, to permit direct diversion into existing channels which could be used for distribution throughout the Suisun marshlands.

The Cordelia Pumping Plant would be designed for 500 second-feet capacity. A 1,300-foot pipeline would convey the water from the pumps to the next reach of aqueduct.

From the discharge line of the Cordelia Pumping Plant, water would flow in concrete-lined canal, having a capacity of 500 second-feet, to a 10-foot diameter, concrete-lined, horseshoe-shaped tunnel extending from Green Valley to Napa Valley. The water would enter this tunnel at an elevation of 99 feet and would be discharged at the Napa Valley portal at an elevation of 82 feet. A concrete-lined canal, with a capacity of 500 second-feet, would lead from the tunnel to a point near Suscol; water would arrive at this point at an elevation of 80 feet.

At Suscol, the water would enter a 10-foot diameter, reinforced concrete pipe with a capacity of 420 second-feet for conveyance across Napa Valley and under the navigable Napa River. Water would be discharged from this pipe at an elevation of 70 feet on the western side of Napa Valley just north of Los Amigos School.

The aqueduct, westward from Los Amigos School to a point near Ramal, approximately two miles southeast of Schellville, would have a capacity of 400 second-feet, and would consist mostly of concrete-lined canal placed along the contour of the hills. A short reach of 10-foot diameter pipe would be used to convey the water across Huichica Creek. At Ramal, the water would enter a nine-foot diameter, reinforced concrete pipe with a capacity of 290 second-feet for conveyance across Sonoma Valley. The aqueduct, consisting of concrete-lined canal with a capacity of 280 second-feet, would follow along the contour of the hills, crossing Highway 37 nears Sears Point at an elevation of 50 feet. Due to the poor surface geologic conditions between Mile 48.3 and Mile 53.6, consideration is being given to constructing a lined tunnel, 4,400 feet in length, and 4,300 feet of lined canal between these points, as indicated on Plate 5. At a point near Lakeville Road, about one mile north of its junction with Highway 37, the water would enter a six-foot diameter reinforced concrete pipe having a capacity of 100 second-feet, for conveyance across Petaluma Valley and under navigable Petaluma Creek. A short reach of concrete-lined canal would then lead to a terminal storage reservoir in the hills northeast of Novato.

The Novato Reservoir would be the terminous of the North Bay Aqueduct. This reservoir would be created by construction of a 40-foot earthfill dam, and would have its normal water surface at an elevation of 32 feet. The capacity of the reservoir would be 570 acre-feet with a surface area of 51 acres. The reservoir would lie immediately north of Atherton Avenue, approximately two miles northeast of the City of Novato.

Offsite Corrective Features. Further study of the water quality considerations of the Junction Point Barrier Plan disclosed that secondary treatment of sewage and industrial wastes entering the Sacramento River in the vicinity of Sacramento would not be a legitimate charge against the plan as indicated in the March 1955 report. It was shown that the dissolved oxygen content of the river is only negligibly affected by the discharge of sewage receiving primary treatment. It was further indicated that the future increases in the sewage output would be offset by the additional flow of water in the river due to operation of the Feather River Project. For these reasons, the cost of the off-site, corrective works, included as features of the Junction Point Barrier Plan, would not be applicable to the Biemond Plan.

Cost. The cost of the Biemond Plan, based upon construction costs which prevailed during 1956, is presented in Table 2. All items include an allowance of 15 per cent for contingencies and 10 per cent for

TABLE 2

SUMMARY OF ESTIMATED COSTS OF THE BIEMOND PLAN [1]

Unit	Amount
Sacramento River	
Control structure	$2,570,000
Lock	1,967,000
Fishway	70,000
Steamboat Slough	
Control structure	2,654,000
Cross-Delta Canal	
Headworks, Sacramento River	1,360,000
Highway Bridge	168,000
Railway Bridge	171,000
Canal, Walnut Grove to San Joaquin River	11,800,000
Canal, Paradise Cut to San Joaquin River	15,980,000
Little Venice Island	
Control structure	2,087,000
Fishway	100,000
Siphon, San Joaquin River	12,050,000
Paradise Cut	
Control structure	922,000
Holland Cut	
Control structure	2,406,000
Lock	1,865,000
Flood control features	
Master levee system	12,500,000
Irrigation and drainage system	1,170,000
North Bay Aqueduct	26,760,000
Subtotal	$96,600,000
Allocation to Feather River Project	—10,400,000
Total Capital Cost	$86,200,000
Estimated Annual Equivalent Cost	
Amortization	3,350,000
Operation, maintenance and replacement	1,439,000
Total	$4,789,000

[1] Based on 1956 construction costs.

administration and engineering, plus interest during construction.

The Cross-Delta Canal was designed to convey water for use in the Delta, Central Valley Project water destined to the Tracy Pumping Plant, water developed by the Biemond Plan, and Feather River Project water to the proposed project pumping plant. As other features of the Biemond Plan would create obstacles to the natural distribution of water in the Delta and the transfer of water to the existing Tracy Pumping Plant, the plan should properly include capacity to overcome these obstacles. However, in the case of the Feather River Project water, facilities provided by the Biemond Plan would eliminate the need for works which would otherwise require construction. As the Feather River Project is authorized for early construction, and as the cross-canal proposed in the Delta as a part of that project could be made to conform to the alignment of the Cross-Delta Canal feature of the Biemond Plan, it was concluded that the Feather River Project should bear a portion of the cost. The amount allocated to that project was $10,400,000. This would be the cost of the works included in estimates of the Feather River Project which would not be necessary under operation of the Biemond Plan.

The estimated annual equivalent cost is also shown in Table 2. The operational cost includes operation and maintenance, replacement and general expense. Variable annual costs such as power were reduced to annual equivalent values.

Water Conservation Aspects of Biemond Plan. The Biemond Plan was designed to conserve a portion of the water now used to repel salinity from the Delta. Under present conditions, a continuous flow of 3,800 second-feet is required to maintain the line of 1,000 parts of chlorides at a point near Antioch. It is tentatively concluded that this could be accomplished with a flow of about 1,200 second-feet with the Biemond Plan in operation. The difference between these two quantities, approximately 2,600 second-feet, would become available for other uses. A portion might be retained in upstream reservoirs; it might be diverted on a constant flow basis to areas of use or to off-stream storage reservoirs; or it might be diverted from the Delta in accordance with demand schedules in the potential service areas. There being no storage associated with the Biemond Plan, the water would either have to be diverted as rapidly as it reached the Delta, or lost to Suisun Bay.

For investigational purposes, it was assumed that salinity control would become the responsibility of the barrier agency. It was further assumed that the present salinity control flows, 3,800 second-feet, would be available for salinity control and disposition by the barrier construction agency. It was also assumed, for use in the economic comparisons, that the amount of water conserved by the Biemond Plan would be that which could be diverted on a firm monthly demand schedule from the Delta to the potential service areas.

As the Act of 1955 contained an urgency measure directing that a study of salinity control barriers be undertaken as a means of supplying fresh water to the areas adjacent to San Francisco Bay, the requirements of the service area of the North Bay Aqueduct would be met before water developed by a barrier project would be distributed to areas outside of the San Francisco Bay Counties. As is shown in Chapter III, the North Bay service area will require approximately 308,000 acre-feet annually by year 2010. That amount was taken from the supplies which would become available under operation of the Biemond Plan, and the remainder, insofar as it would supply firm water, was assigned to San Joaquin Valley. The estimated potential demand for irrigation water in the San Joaquin Valley is shown in Table 3.

TABLE 3

ESTIMATED POTENTIAL AGRICULTURAL WATER SALES IN SAN JOAQUIN VALLEY

(In acre-feet)

Year	Amount
1960	0
1965	500,000
1970	1,000,000
1975	1,250,000
1980	1,500,000

The monthly demand schedules for water in the San Joaquin Valley and the North Bay Aqueduct service areas are shown in Table 4.

TABLE 4

MONTHLY DISTRIBUTION OF ANNUAL WATER DELIVERIES FROM SALINITY CONTROL BARRIER TO PROJECT SERVICE AREAS

(In per cent)

Month	San Joaquin Valley, irrigation schedule	North Bay Counties	
		Urban schedule	Irrigation schedule
January	4	7.0	0
February	5	6.4	0
March	6	7.0	2.0
April	5	8.1	8.6
May	4	8.8	11.8
June	12	10.0	17.3
July	18	10.2	19.4
August	18	10.1	17.9
September	13	9.6	13.8
October	8	8.7	7.0
November	4	7.2	2.2
December	3	6.9	0
Totals	100	100.0	100.0

It was determined that up to 629,000 acre-feet could be diverted to San Joaquin Valley annually without regulatory storage. The total annual amount of water which could be conserved by the Biemond Plan under the stated conditions would be 937,000 acre-feet.

If the unallocated portion of the salinity control flows (the remainder after operational losses in the Delta and diversion into the North Bay Aqueduct) could be diverted from the Delta and regulated in an offstream storage reservoir, the amount of water conserved by the Biemond Plan could be more than doubled.

If 510,000 acre-feet of offstream regulatory storage were provided, the Biemond Plan would conserve about 1,900,000 acre-feet of water annually, including water taken directly from the Delta for use in the North Bay Aqueduct service area. This would require facilities, leading to an offstream reservoir of 2,450 second-foot capacity, only 600 second-feet larger than those which would be required to meet the demand schedule shown in Table 4 without regulatory storage. While the investigation of sites for offstream reservoirs was beyond the scope of the present study, their potential value, when operated in conjunction with the Biemond Plan, should be recognized.

Economic Justification of Biemond Plan. The benefits and detriments of the Biemond Plan were evaluated for the 50-year period beginning in 1961 and ending in year 2010. This appraisal was made solely for the purpose of comparing the Biemond Plan with the Chipps Island Barrier Plan, hereinafter described. In view of this fact, a hypothetical service area in San Joaquin Valley was assumed for disposal of water beyond the needs of the San Francisco Bay Counties and the benefits of supplying water to that area were computed.

Benefits of Water Conserved. The largest project benefit would result from water made available for irrigation purposes. Irrigation benefits which would occur in the North Bay Aqueduct service area were derived from a detailed study of the productivity of agricultural land with and without irrigation. The average annual equivalent difference between the total net income under project conditions and the total net income under pre-project conditions was used as the measure of the direct benefit. Benefits were computed at points of use and all costs of distribution from the aqueduct to points of use were deducted therefrom in order to derive the net benefits at the aqueduct. Indirect benefits were not included in the analysis.

Similar studies were made of the benefits of irrigation water applied to land in the San Joaquin Valley. Only direct benefits were considered and were derived at the point of diversion from the Delta. The distribution system costs and the cost of a main conveyance aqueduct from the Delta to the service area were deducted as associated costs in the derivation of the net benefits. The inclusion of the main aqueduct costs as associated costs, rather than as project costs, is at variance with usual practice and exaggerates the benefit-cost ratio. However, a main aqueduct to the San Joaquin Valley was not included as a project feature and, therefore, was not included as a project cost.

Benefits which would result from the use of water for municipal and industrial purposes in the service area of the North Bay Aqueduct were measured by an assumed sale price of $30 per acre-foot based upon vendibility and cost of alternative supplies. It is emphasized that this is merely an assumption used in the economic comparisons of the two barrier plans and in the financial feasibility study of the North Bay Aqueduct.

Benefits of Flood Control. The benefits of flood control to the Delta landowners would be two-fold. The islands would be (1) protected against crop damage, cost of re-establishing the agricultural enterprise

and repair of levee breaks, and (2) decrease in operation and maintenance of interior levees due to controlled lower water stages. The analysis of benefits to agriculture was based upon crop patterns for each island, costs of re-establishing the agricultural enterprise, and the frequency of flooding under present conditions as developed in studies made by the Corps of Engineers.

Benefits of Cross-Delta Canal. As noted above, the principal benefits of the Biemond Plan were measured in terms of the water conserved and the flood protection afforded. However, a significant and far reaching benefit would also be obtained from improvement of the quality of water diverted from the Delta for use in the San Joaquin Valley. The Cross-Delta Canal would make it possible to convey high quality water to the major pumping plants in lieu of a mixture of San Joaquin River water, drainage water from the Delta, sea water and Sacramento River water which is now being exported. While the monetary value of this improvement in water quality was not determined, a benefit would exist and, therefore, warrants mention.

The Cross-Delta Canal feature of the Biemond Plan would also deliver water of better quality throughout the Delta. Here again, a monetary value was not placed on this benefit; however, the improved quality of water would probably require less leaching of the soils than is now necessary, and would increase the crop yields.

Detriments to Navigation. The Biemond Plan would not interfere with ocean-going and other waterborne traffic destined to, from or between, the Ports of Stockton and Sacramento. The plan would however cause lockage delays to tug and barge movements along the Sacramento River and in the Delta proper. The value of these delays, developed from estimates of traffic and locking times, was assessed against the project as a detriment.

Detriments to Fish and Wildlife. The Biemond Plan would decrease the populations of certain species of fish and would increase the populations of other species. Moving water, such as tidal currents afford, is essential to successful spawning of striped bass. The elimination by the Biemond Plan of many of the tidal channels in the Delta would reduce the spawning area. The reduction in area of channels would also affect the available wintering area of the striped bass. The control structures would be physical obstructions to the upstream migration of anadromous species, principally striped bass and shad and, to a lesser extent, salmon and steelhead. These factors would tend to decrease the anadromous fish populations. Although the anadromous species would be adversely affected by the Biemond Plan, the warm water species would be benefited since the channels eliminated from tidal action would be ideal for warm water fish.

To permit analysis of the economic value of the effect of the Biemond Plan on recreational fishing, it was necessary to express the losses and gains in terms of fisherman days and assign a value to a fisherman day. The Department of Fish and Game evaluated the reduction in fisherman days which would be caused by a reduction of the anadromous species and also the increase due to increased warm water species. The average daily gross expenditure by a fisherman is a measure of the economic value of a fisherman day. However, this amount is considered unapplicable since the gross expenditures per day would be much more than the direct benefit or detriment.

A similar problem in the evaluation of the direct benefit of a recreation day was studied in connection with the investigation of the Upper Feather River Basin (Department of Water Resources Bulletin No. 59) by the firm of Harold F. Wise and Associates, City and Regional Planners, for the Department of Water Resources under terms of a service agreement. Dr. Andrew H. Trice, of Harold F. Wise and Associates, analyzed the expenditures of several hundred recreationists and concluded that about $2.00 per day would be a reasonable measure of the primary benefit of a recreationist day. The total value of the detriments to recreational fishing caused by the Biemond Plan were computed as the product of the fisherman days times $2.00 per day.

A reduction of salmon and shad due to the Biemond Plan would also be detrimental to commercial fishing interests. The economic value of commercial fish should be the detriment to the commercial fisherman as he suffers the initial loss. The net income of the commercial fisherman was considered as the primary detriment. This was estimated to be 20 per cent of the price which the fisherman receives for his catch. The weight of the commercial catch was estimated by the Department of Fish and Game.

Net Benefits. The net benefits of the Biemond Plan were computed as the difference between the

TABLE 5

ANNUAL EQUIVALENT NET BENEFITS OF THE BIEMOND PLAN

Item	Amount
Benefits	
Irrigation water	$8,960,000
Municipal and industrial water	979,000
Flood control	1,152,000
Subtotal	$11,091,000
Detriments	
Navigation	13,000
Fish and wildlife	228,000
Subtotal	$241,000
Net benefits	$10,850,000

benefits and detriments described in the foregoing sections. The benefits and detriments are summarized in Table 5.

Benefit-Cost Ratio. The benefit-cost ratio of the Biemond Plan is based upon the annual equivalent net direct benefits presented in Table 5, \$10,850,-000 and the annual equivalent costs presented in Table 2, \$4,789,000. The resultant ratio of net direct benefits to costs is 2.3:1.

It is recognized that many indirect and intangible benefits would result from the construction of the Biemond Plan. These benefits have not been evaluated and, therefore, are not included in the derived benefit-cost ratio.

Comparison of Junction Point Barrier Plan With Biemond Plan

A comparison of the capital costs of the Junction Point Barrier Plan, as described in the report entitled "Feasibility of Construction by the State of Barriers in the San Francisco Bay System," and of the Biemond Plan is shown in Table 6. The capital costs of the Junction Point Barrier Plan were adjusted, by use of the Engineering News Record construction cost index, to reflect prices which prevailed during 1956. The construction cost indexes for 1954 and 1956 were 628.0 and 692.4, respectively.

TABLE 6

COMPARISON OF JUNCTION POINT BARRIER PLAN WITH BIEMOND PLAN

Item	Junction Point Barrier Plan[1]	Biemond Plan[1]
Principal structures	\$31,450,000	\$16,340,000
Siphon	14,580,000	12,050,000
Flood control features	31,920,000	[2]12,500,000
Cross-Delta Canal	17,460,000	27,780,000
Irrigation and drainage features	3,930,000	1,170,000
North Bay Aqueduct	36,360,000	26,760,000
Subtotals	\$135,700,000	\$96,600,000
Allocation to Feather River Project	—10,400,000	—10,400,000
Total Capital Cost	\$125,300,000	\$86,200,000

[1] Based on 1956 construction costs.
[2] Exclusive of flood control costs for Mokelumne River and Paradise Cut which are included in the costs of the Cross-Delta Canal.

CHIPPS ISLAND BARRIER PLAN

The Chipps Island Barrier Plan is an example of operation under the mixing concept. Water would enter the barrier pool from (1) the Sacramento River (2) the San Joaquin River system, (3) Suisun Bay through lock operation, and (4) rising ground water in the Delta. During critically dry summer months the water entering from Sacramento River would be of excellent quality; that from the San Joaquin River and Delta would be high in total dissolved solids; while that entering from Suisun Bay would be high in chloride content. Successful operation of the Chipps Island Barrier Plan would require either complete mixing of the incoming waters, or interception and disposal of the poor quality water to some point below the principal works.

The construction of the Chipps Island Barrier Plan as described in the March 1955 report would place physical structures between the saline water of the San Francisco Bay system and the flows of the Sacramento and San Joaquin River systems. These structures would be located near the City of Pittsburg and would follow the general alignment of the Sacramento Northern Railway right of way across Chipps Island and Van Sickle Island. With the Chipps Island Barrier Plan in operation, the dividing line between salt water and usable fresh water would be at the physical structures. This would eliminate the need for further consideration of the line of 1,000 parts of chlorides as discussed in the introduction of this chapter and shown on Figure 2. The principal features would consist of the barrier embankment, three floodway structures, four navigation locks, a salt-scavenging system, a fishway and a system of levees in the Delta. Details of the principal works are shown on Plate 6, "Layout of Principal Structures, Chipps Island Barrier Plans," and the flood control features are shown on Plate 7, "Chipps Island Barrier and Delta Flood Control Plan."

Modified Chipps Island Barrier Plan

The studies of the Chipps Island Barrier Plan, directed by the Act of 1955, disclosed the advantages of making minor modifications to the plan as described in the March 1955 report. Changes were also found to be needed in the previous economic appraisal. The studies conducted and the resultant modifications are hereinafter discussed. The reader is directed to sections of Plate 6 and to Plate 8, "Modified Chipps Island Barrier and Delta Flood Control Plan."

Barrier Embankment. Subsequent to completion of the investigation authorized by the Act of 1953, the Sacramento Northern Railway was granted permission to abandon service across Chipps and Van Sickle Islands. As its trackage closely followed the Chipps Island barrier alignment, study was made of the feasibility of acquiring the railway right of way to take advantage of any compacted fill which might exist. Field reconnaissance, however, disclosed that a major portion of the track was located on trestles, and that the removal of these structures would become an added consideration. However, the railroad is laid upon an embankment across most of Chipps Island. Part of this embankment would have to be removed during excavation for the locks and fishway. The remaining portion would have to be raised to a much

higher elevation. As very little information was available regarding the existing embankment, and because of the poor foundation conditions which prevail throughout the area, it was concluded that the abandoned railway right of way offered only negligible, if any, advantages over the original alignment. Therefore, no changes were made to the original design of the barrier embankment. The barrier embankment of the Chipps Island Barrier Plan would consist of four levee sections: (1) from high ground in Contra Costa County to the Sacramento River, (2) across Chipps Island, (3) across Van Sickle Island, and (4) from Montezuma Slough to high ground northwest of Collinsville in Solano County. The total length of embankment would be about 22,000 feet. The design and cost of this embankment was based upon predredging of the soft peat material and construction of a sand levee to elevation 15 feet, mean sea level datum. The levee would have 5:1 side slopes, a top width of 30 feet, and riprap protection at critical points.

Floodway Structures. A review of the studies pertinent to the Chipps Island floodway structures failed to disclose a need for further work in the field of structural design and operation. The small storage area upstream from the Chipps Island barrier would require that floodways be provided equal in area to the present channels. This would be accomplished by constructing floodways of similar design but of different sizes across the Sacramento River, Spoonbill Creek and Montezuma Slough.

The floodway across the Sacramento River would provide 115,200 square feet of opening below mean sea level and would consist of a pile-supported, concrete apron, piers and abutments, and 48 fixed-wheel, vertical-lift, steel gates, each 60 feet wide and 48 feet deep with gate sills 40 feet below mean sea level. The gate piers would support a hoist frame and deck for raising the gates, and two service bridges with 15-foot roadways. The floodway across Spoonbill Creek would provide 1,800 square feet of area, below mean sea level, by means of three gates, each 40 feet wide and 23 feet deep with sills 15 feet below mean sea level. The Montezuma Slough structure would provide 4,000 square feet of opening, below mean sea level, through five gates each 40 feet wide and 28 feet deep with gate sills 20 feet below mean sea level.

Preliminary results, obtained from operation of an electronic analog, indicated that a Chipps Island barrier might increase the tidal amplitude at the site by five feet. If this were to occur, the floodway gates would be subjected to forces beyond which were originally contemplated, and would, in fact, be nearly topped. Time did not permit redesign of the necessary structures to overcome this problem. For this reason, the estimated cost of the Chipps Island floodway structures must be recognized as *too low*.

Navigation Locks. The lock sizes and number recommended for inclusion with the Chipps Island Barrier Plan were reviewed and found acceptable by the members of the San Francisco District, Corps of Engineers. These data are shown in Table 7.

TABLE 7

NUMBER AND SIZE OF LOCKS IN THE CHIPPS ISLAND BARRIER PLAN

Number	Length, in feet	Width, in feet	Depth of sill, in feet below mean sea level
2	800	96	40
1	[1]600	86	18
1	[1]300	45	16

[1] Gated at midpoint.

The review of the functional feasibility of the Chipps Island Barrier Plan revealed the need for improving the quality of water in the barrier pool. The conclusions presented in the March 1955 report pointed out that the quality of water would be dependent upon the amount of sea water which would enter through the locks. Only limited information was available on this matter and an estimate of the amount had to be based largely on judgment.

It was concluded that as much as 10 per cent of the invading salt might be dispersed throughout the barrier pool and it was shown that this would render the water unusable during periods of critical water supply.

Model studies conducted by the United States Waterways Experiment Station, Vicksburg, Mississippi, and published in 1946, indicated that the use of salt-clearing locks would greatly reduce the salt transfer into the upper pool over that which would be expected with conventional locks. Investigation disclosed that with salt-clearing locks and a small salt-scavenging system, the water in the Chipps Island barrier pool would be of Class I quality, if complete mixing of the incoming water was accomplished in the pool. As the construction of a barrier plan would be disastrous were the quality to be unacceptable, the original Chipps Island Barrier Plan was modified to include salt-clearing locks.

A salt-clearing lock is one which is designed with separate filling and emptying systems which permit flushing of the sea water with fresh water during the locking procedure. The salinity of water in the lock is thereby reduced to tolerable limits and only a small amount of salt would actually invade the fresh water pool.

The redesign of the navigation locks for the Chipps Island Barrier Plan was accomplished in accordance

with data provided by the San Francisco District, Corps of Engineers. The same number and size of locks, as shown in Table 7, were used. The location and orientation of these locks, as well as sectional views are shown on Plate 6.

Provisions were included in the plan for providing tug assistance to unwieldy vessels passing through the locks. One tug, and a wharf equipped with administration quarters, storage and fueling facilities were provided. These facilities would be operated on a 24-hour basis.

Salt-scavenging System. With the introduction of salt-clearing locks into the Chipps Island Barrier Plan, it became feasible to greatly reduce the size of the originally planned salt-scavenging system.

The main scavenger pipe would be five feet in diameter. A detention sump 500 feet wide, 1,000 feet long and having its bottom 55 feet below mean sea level, would be dredged in front of the lock. Multiple inlet collection pipes would be located in the bottom of the sump and wye-connected to the main pipe. Each inlet pipe would be 100 feet long and three feet in diameter.

Fishway. Changes were not made in the previous design of a fishway to operate with the Chipps Island Barrier Plan. The fishway would be of the vertical baffle type. It would consist of a rectangular, concrete channel, 20 feet wide, 24 feet deep and approximately 600 feet long. The floor of the channel would be 14 feet below mean sea level to provide a minimum water depth of 10 feet at low tide. The channel would have cross walls at intervals with vertical slot openings for water flow and passage of fish. The cross walls would serve as baffles to dissipate energy. The channel would be equipped with a radial gate to prevent salt water flow into the barrier pool during periods of high tide.

Flood Control Features of the Chipps Island Barrier Plan. The Biemond principle of restricting flood flows to specified channels was further explored in connection with the Modified Chipps Island Barrier Plan. The resultant flood control plan, also shown on Plate 8, would confine flood waters of the Sacramento River system to the Sacramento River, Steamboat Slough and the Yolo By-Pass. Flows of the Mokelumne River would be restricted to the North Fork of the Mokelumne River. Flood water of the San Joaquin River would follow the same channels as in the Biemond Plan, namely, the San Joaquin River and Paradise Cut, Grant Line Canal, Old River and Holland Cut. The Calaveras River would also carry the diverted flows of Bear Creek. Franks Tract would remain inundated.

The modified plan, as shown on Plate 8, would require approximately 418 miles of levee including 190 miles in the Sacramento River Flood Control Project and 58 in the authorized Lower San Joaquin River Tributaries Project as compared with the 992 miles of levees under the present system. As with the Biemond Plan, the interior channels, severed during construction of the master levee system, would be used to distribute water for irrigation of the Delta, and for drainage thereof.

North Bay Aqueduct. The reanalysis of the alternative North Bay Aqueduct alignments indicated that a system of works diverting water from Lindsay Slough would be the most economical for inclusion with the Chipps Island Barrier Plan. The North Bay Aqueduct of the Chipps Island Barrier Plan would, therefore, be identical with that previously described for the Biemond Plan and shown on Plate 5.

Offsite Corrective Features. Treatment and/or disposal of sewage and industrial wastes entering a Chipps Island barrier pool would be required to maintain quality standards. It was found that wastes from some of the industrial plants could not economically be treated and would, therefore, have to be collected, conveyed and discharged into Suisun Bay below the barrier. However, the majority of the wastes, with secondary treatment. could be returned to the pool and re-used.

In estimating the cost of treatment of these wastes, it was assumed that primary treatment is in the public interest and, therefore, only the cost of constructing the secondary treatment facilities would be charged to the barrier project. The annual operational costs, including maintenance and replacement were assumed to be borne by the owners of the plants.

The industrial wastes which are strongly mineralized or high in oil and phenolic substances would require diversion around the barrier. The capital costs of the diversion system would be borne by the barrier project as well as the annual maintenance and operation costs.

The creation of a nearly quiescent lake in the Delta by construction of the Chipps Island barrier would require special facilities to dispose of warm industrial return waters now being diffused by tidal currents. These facilities would be necessary to protect the fish from abrupt temperature changes. As in the case of the sewage treatment plants, only the capital cost of the dispersion works were assessed against the barrier project; operation and replacement costs were assumed to be borne by the industries.

The salt-scavenging sump, placed just upstream from the locks, would capture a portion of the river's sediment load. The annual cost of removing this material was charged against the project.

A review was made of the salt routing studies conducted during the previous investigation. It was found that with salt-clearing locks, the mineral quality of water in the Chipps Island barrier pool would

be acceptable. However, in the event that a master drain is planned to deliver low quality irrigation return flows from the entire San Joaquin Valley, prior to its construction reanalysis of its effects on the Chipps Island barrier pool would be necessary. It is conceivable that with a Chipps Island Barrier Plan in operation, the drain from San Joaquin Valley would have to discharge directly to Suisun Bay.

If the Chipps Island barrier were to greatly increase the tidal amplitude in Suisun Bay, as indicated by operation of the electronic analog, an extensive levee system would be required in the Suisun marshlands and along the Contra Costa County shore. It is indicated that under certain conditions, a water stage of about 12 feet, mean sea level datum, would be experienced at the barrier; a stage of about 10 feet would be expected at Benicia. A very preliminary estimate was made of a master levee system to protect the Suisun marshlands and the southern shore of Suisun Bay in Contra Costa County. This system would cost about $11,000,000 if it were constructed over a period of years to allow for foundation consolidation. However, it would cost about $17,000,000 if it were constructed in a few years since special foundation treatment would be required. In addition to levee protection, the change in tidal amplitude would lower low-water stages and make it necessary to dredge the navigation channels and berthing areas. It would also be necessary to modify the plants of industries and military installations on the shores of Suisun Bay. The costs of dredging and plant modifications were not evaluated. Since the magnitude of the increase in tidal amplitude has not been firmly established, the costs of the resultant offsite corrective features were not included as costs of the Chipps Island Barrier Plan. However, the possibility of a change in tidal amplitude and resultant increase in cost of the plan must be recognized.

Cost. The costs of the Chipps Island Barrier Plan, modified as noted, but not including costs which would result from a change of tidal amplitude in Suisun Bay, are presented in Table 8. The estimated costs are based upon construction prices which prevailed during 1956. The cost of those elements of the original plan, which were not redesigned, were adjusted by means of the Engineering News Record construction cost indexes to reflect the 1956 prices. It is emphasized that the costs for modifications which would be required by an increase in tidal amplitude are not included.

The Modified Chipps Island Barrier Plan would eliminate the need for the proposed Cross-Delta Canal of the Feather River Project which would follow, for the most part, existing sloughs and channels but which would require enlarging. Under the Modified Chipps Island Plan, the existing channels north of

TABLE 8

SUMMARY OF ESTIMATED COSTS OF THE MODIFIED CHIPPS ISLAND BARRIER PLAN [1]

Item	Amount
Barrier embankment	$5,580,000
Floodway structures	57,640,000
Navigation locks and tug facilities	67,640,000
Salt-scavenging system	1,400,000
Fishway	460,000
Flood control features	
Master levee system	29,750,000
Irrigation and drainage system	1,020,000
Offsite corrective features	19,050,000
North Bay Aqueduct	26,760,000
Subtotal	$209,300,000
Allocation to Feather River Project	—10,400,000
Total Capital Cost	$198,900,000
Estimated Annual Equivalent Cost	
Ammortization	7,730,000
Operation, maintenance and replacement	3,236,000
Total	$10,966,000

[1] Based on 1956 construction costs.

the San Joaquin River would have adequate capacity, and Old River and Holland Cut south of the San Joaquin River would be enlarged for flood channels. The saving to the Feather River Project, $10,400,000, was considered as a deductible cost chargeable to the Feather River Project.

The estimated annual equivalent cost is also shown in Table 8. The operational cost includes operation and maintenance, replacement and general expense. Variable annual costs such as power were reduced to annual equivalent values.

Water Conservation Aspects of Chipps Island Barrier Plan. The amount of water which could be conserved by the Chipps Island Barrier Plan would directly reflect basic conditions regarding inflow to the pool, area of the pool, operating range in the pool, type and location of demand for water from the pool, and operational losses. The only water considered as inflow to the pool was that which would be required under present conditions, to maintain the line of 1,000 parts of chlorides at a point near Antioch shown in Figure 2. The amount of water required has been established as 3,800 second-feet.

The surface area of the Modified Chipps Island barrier pool, 36,400 acres, would be less than that of the original plan (38,200 acres), due to the master flood control levee system in the Delta even though Franks Tract would remain open under the modified plan. The evaporation considered as a loss chargeable to the plan was computed only on the 2,900 acres of water surface between the barrier and the desired location of the 1,000 part line near Antioch. Evaporation from the remaining area is supplied from some other

source under present conditions and would not be reflected in the 3,800 second-feet of salinity control flow.

In addition to the loss of water from the pool due to evaporation, there would be unavoidable losses through operation of the locks, salt-scavenging system and fishway. Studies of these water requirements were made under conditions which were estimated to occur in the year 2010. The amount of fresh water required to accommodate the water-borne traffic was based upon one lockful of water per passage, including scavenging of the invading salt.

The fishway at Chipps Island would require an average flow of 200 second-feet to pass anadromous fish across the barrier. This flow would vary depending upon the stage of the fresh water pool and tidal conditions.

In the previous investigation of barriers, studies were made of three operating conditions—no conservation operating range, a three-foot operating range, and a six-foot operating range. It was shown that the amount of water conserved would increase with the increase in range. Although offsite corrective costs would result from a six-foot range, the additional benefits from increase in yield would be greater than the corrective costs. In the modified plan, the Delta would be provided with a master levee system capable of withstanding higher water stages under flood conditions than those of a six-foot operating range. Therefore, the six-foot range was accepted for water conservation study purposes.

The monthly demand schedules used in determining the water conservation benefits of the Modified Chipps Island Barrier Plan were the same as used for similar studies of the Biemond Plan. Those schedules are shown in Table 4. As in the case of the Biemond Plan, water would first be assured for the North Bay Aqueduct service area, with the remaining water used in the San Joaquin Valley. It was assumed that water would be delivered to the service areas in accordance with their monthly demands without deficiency in any year.

Under the established conditions, the Chipps Island Barrier Plan would conserve about 1,675,000 acre-feet of water annually from flows now used to repel salinity. Of this amount, 308,000 acre-feet would be available to the North Bay service area, and 1,367,000 acre-feet would be exported to the San Joaquin Valley. To meet the monthly demands in the San Joaquin Valley as shown in Table 4, it would require diversion facilities from the Delta with capacity for about 3,950 second-feet.

The yield of the Chipps Island Barrier Plan could be increased by supplementing the regulatory storage in the Delta with offstream storage along the aqueduct leading to the San Joaquin Valley. If 530,000 acre-feet of additional storage were provided, the plan would yield approximately 2,400,000 acre-feet annually, including the water taken directly from the Delta for use in the North Bay service area. This would not require an increase in the capacity of the diversion facilities leading to the offstream reservoir.

Economic Justification of Chipps Island Barrrier Plan. The benefits and detriments of the Chipps Island Barrier Plan were reduced to monetary values for comparison with those of the Biemond Plan. As noted in discussions of the Biemond Plan, both plans were evaluated for the 50-year period beginning in 1961 and ending in year 2010.

Benefits of Water Conserved. The largest benefit of the Chipps Island Barrier Plan would be that resulting from use of the 1,675,000 acre-feet of conserved water. It was estimated that all but 132,000 acre-feet of this water would be used for irrigation of agricultural lands in 2010; 132,000 acre-feet would be used for urban purposes in the service area of the North Bay Aqueduct.

Benefits of water for irrigation were determined from detailed studies of the net income from the land in the service areas (North Bay and San Joaquin Valley) with and without irrigation. Benefits were measured at project facilities, i.e., at the Delta or at the North Bay Aqueduct. The costs of all other works necessary to deliver the water from these points to the land were deducted as associated costs.

Benefits which would result from use of water for municipal and industrial purposes in the North Bay Aqueduct service area were measured by an assumed sale price of $30 per acre-foot based upon vendibility and cost of alternative supplies. This assumed price was used merely for the economic comparison of the two barrier plans and is not to be taken as the firm sales price from the aqueduct.

Benefits of Flood Control. For comparison purposes, it was assumed that the flood control benefits to agricultural enterprises from operation of the Chipps Island Barrier Plan and the Biemond Plan, would be equal since the same area would be protected. There, however, would be a slightly less benefit from decreased levee maintenance with the Chipps Island Barrier Plan than with the Biemond Plan due to different lengths of levees. The factors considered in the determination of these benefits were described under the Biemond Plan.

The improvement of water quality in the Delta would be less for the Chipps Island Barrier Plan than for the Biemond Plan. Return irrigation water from the Delta would find its way to the major diversions. The quality of water in the Delta would, however, be expected to improve over present conditions, due to the exclusion of salt water from Suisun Bay. The benefit of this water quality improvement was not evaluated for either the Chipps Island Barrier Plan

or the Biemond Plan. As the benefits would not be equal, this would tend to favor the Chipps Island Barrier Plan.

Transportation. Studies conducted during the investigation leading to the March 1955 report, concluded that a Chipps Island barrier would be beneficial for use as a vehicular transportation crossing. Since completion of those studies, a bridge has been authorized, and is currently under construction across Carquinez Strait near Vallejo and a bridge has been authorized for construction between Martinez and Benicia. These two occurrences, plus the adoption of a more liberal Federal aid highway program, rendered the previous studies obsolete.

In view of the changed condition, a service agreement was executed between the Division of Highways of the Department of Public Works and the Department of Water Resources for a reappraisal of the warranty of a Chipps Island vehicular crossing. The service agreement provided that the Division of Highways:

"1. . . . shall conduct an investigation of the economic warranty of a vehicular crossing between Contra Costa and Solano Counties in the vicinity of Chipps Island. The investigation shall include:

"a. An evaluation of vehicle time and distance which would be conserved to the traveling public by construction of a vehicular crossing in the vicinity of Chipps Island.

"b. An estimate of the cost of the approach freeways.

"c. A statement of the complications involved in the integration of this route in the California and interstate highway systems."

The report submitted by the Division of Highways on October 11, 1956, concluded as follows:

". . . The estimated worth of the costs in 1960, based on a total net 50-year cost of $105,789,000 at three per cent interest, is $91,100,000. This amount does not compare favorably with the worth of the benefits in 1960 of $56,500,000. It is concluded that the project is not economically warranted.

"Integration of the proposed route in the State Highway System would require Legislative authorization (Section 24 of the Streets and Highways Code) and subsequent action by the California Highway Commission for adoption of more precise portions of the route.

"Integration of the proposed route in the Interstate System would require approval of the Secretary of Commerce. A 40,000 mile Interstate System has already been designated and it is not likely that the proposed route could be recommended for inclusion in the additional 1,000 miles authorized by the 1956 Act, because of its proximity to the highly important Interstate Route along U. S. 40."

In view of these conclusions, transportation benefits should not be assigned to the Chipps Island Plan.

Detriments to Navigation. The construction of a Chipps Island barrier would cause a delay to all deep draft water-borne traffic destined to or from the Ports of Stockton and Sacramento. It would also interfere with the free movement of tugs and barges from Bay ports to inland waters. The introduction of salt-clearing locks into the plan would further increase the time of delay as indcated in Table 9.

TABLE 9

AVERAGE TIME FOR LOCKING VESSELS THROUGH CONVENTIONAL AND SALT-CLEARING LOCKS

(In minutes)

Type of vessel	Conventional locks	Salt-clearing locks
Steamers	35.0	47.0
Tugs	19.5	21.5

The economic value of the delay to navigation interests was appraised, using the estimated traffic and cost of operations shown in the March, 1955 report.

Detriments to Fish and Wildlife. The Chipps Island Barrier Plan would have an adverse effect on fish for reasons similar to those described under the Biemond Plan. However, the affect of the Chipps Island Barrier Plan would be more severe than with the Biemond Plan. The losses of anadromous species and gains of warm water species under the Chipps Island Barrier Plan were estimated by the Department of Fish and Game. The analysis of the value of the losses and gains was made as described under the Biemond Plan.

Detriments to Offset Features. A review of the sanitary considerations of a Chipps Island barrier pool confirmed the conclusions drawn in the previous study that severe oxygen depletion would be expected under future conditions if only primary treatment of organic wastes were provided. Therefore, the previous estimates of cost for preventative facilities were brought to 1956 levels and assessed against the Chipps Island Barrier Plan. The added cost of operating these facilities, assumed to be borne by some other agency, were carried as detriments.

Net Benefits. The net benefits of the Modified Chipps Island Barrier Plan were computed as the difference between benefits and detriments described

TABLE 10

ANNUAL EQUIVALENT NET BENEFITS OF THE MODIFIED CHIPPS ISLAND BARRIER PLAN

Item	Amount
Benefits	
Irrigation water	$15,596,000
Municipal and industrial water	979,000
Flood control	1,146,000
Subtotal	$17,721,000
Detriments	
Navigation	$112,000
Fish and wildlife	951,000
Offsite features	485,000
Subtotal	$1,548,000
Net benefits	$16,173,000

in the foregoing sections. The direct benefits and detriments are summarized in Table 10.

Benefit-Cost Ratio. The benefit-cost ratio of the Modified Chipps Island Barrier Plan was based upon the annual equivalent net benefits presented in Table 10, $16,173,000, and the annual equivalent cost presented in Table 8, $10,966,000. The resultant ratio of benefits to cost was found to be 1.5 to 1.

It is emphasized that the cost of the Modified Chipps Island Barrier Plan, used in the derivation of the benefit-cost ratio, does not include the cost of remedying possible offsite damages which might be caused by a change in tidal amplitude. If remedial works were required, the benefit-cost ratio would be less than 1.5:1.

Comparison of Chipps Island Barrier Plans

A comparison of the original Chipps Island Barrier Plan with the Modified Chipps Island Barrier Plan is presented in Table 11. The capital costs of the original plan were indexed upward by use of the Engineering News Record construction cost index to reflect construction costs which prevailed in 1956. The South Bay Aqueduct is not included in this comparison since it is an authorized feature of the Feather River Project.

TABLE 11

COMPARISON OF COSTS OF ORIGINAL AND MODIFIED CHIPPS ISLAND BARRIER PLANS

Item	Original plan[1]	Modified plan[1]
Barriers and appurtenant facilities	$128,110,000	$132,720,000
Flood control features	39,500,000	29,750,000
Irrigation and drainage system	3,930,000	1,020,000
Offsite corrective costs	19,050,000	19,050,000
North Bay Aqueduct	27,060,000	26,760,000
Subtotals	$217,650,000	$209,300,000
Allocation to Feather River Project	—10,400,000	—10,400,000
Total Capital Cost	$207,250,000	$198,900,000

[1] Based on 1956 construction costs.

CHAPTER III

SAN FRANCISCO BAY COUNTIES WATER PLAN

". . . initiate the further investigation and study . . . for the purposes of developing complete plans of the means of accomplishing delivery of fresh water to the San Francisco Bay area . . ."

The above quotation is taken from the Abshire-Kelly Salinity Control Barrier Act of 1955. The Act further specifies that the study is to include the Counties of Solano, Sonoma, Napa, Marin, Contra Costa, Alameda, Santa Clara, San Benito, and San Mateo, and the City and County of San Francisco. Portions of this area lie in four principal hydrographic areas of the State: San Francisco Bay Area, North Coastal Area, Central Valley Area and Central Coastal Area. As these counties have many and varied water problems, the following discussion is by the hydrographic areas as shown on Plate 9, "San Francisco Bay Counties Water Plan." Those portions of the counties which drain to Suisun, San Pablo and San Francisco Bays are defined as being within the San Francisco Bay Area; those areas draining to the Russian River are within the North Coastal Area; those areas draining into the Sacramento River or its tributaries are within the Central Valley Area; and those areas tributary to the Pajaro River are within the Central Coastal Area.

Investigations leading to the development of a water plan normally begin with a determination of basic hydrologic phenomena of precipitation and runoff, i.e., water supply. However, for the present purpose, these basic studies were not required as a large amount of hydrologic information had been gathered, compiled and published by the State Water Resources Board, the Water Project Authority, offices of the Geological Survey and Bureau of Reclamation of the United States Department of Interior, the San Francisco District, Corps of Engineers, local districts and private engineers. By application of information found in reports of these agencies, it was possible to "initiate the further investigation" without intensive new field investigations of water supply. The present study was one of continuing and refining the estimates of future water requirements presented in "Economic Development of San Francisco Bay Area," dated October, 1955, which constitutes Appendix A of the March 1955 report. As the objective was to develop "complete plans," it was necessary to establish the conditions under which the complete plans were to be developed.

The California Water Plan, a complete plan for comprehensive development of the water resources of the entire State, is nearing completion. This plan was conceived as a guide to the orderly development by logical progressive stages of numerous individual projects. When constructed, The California Water Plan would be capable of distributing water to all areas of the State at a time when all potentially irrigable land is either under irrigation or inhabited, and when our cities have reached a state of equilibrium. Having available a plan capable of meeting the water requirements of all areas at some distant, but unspecified, time in the future, it was concluded that the present task was to determine which projects of The California Water Plan could best satisfy conditions which would be encountered during the next 50 years.

It was found that different conclusions could be drawn from different sets of basic criteria. The basic criteria upon which a water plan for the San Francisco Bay Counties was developed are as follows:

1. The plan is to include facilities capable of supplying sufficient quantities of water to meet the demands of the study area during the period beginning in 1960 and ending in year 2010.
2. The plan is to be designed to develop and convey water for both municipal and agricultural uses; distribution and treatment of said water shall be the responsibility of local agencies.
3. Sufficient water should be reserved to meet the future needs of the area of origin before consideration is given to exporting water from that area.
4. The plan should be designed to supplement, rather than supersede, existing water resources developments to the fullest extent possible.
5. The need for the plan is to be demonstrated.
6. Projects of the plan should be economically justified and financially feasible at the time of construction.
7. There should be a demonstrated desire for projects by a majority of the beneficiaries thereof.

The San Francisco Bay Counties Water Plan was conceived to supply sufficient water to meet all supplemental water requirements until year 2010. Supplemental water requirements were developed from estimates of population and land use, estimates of future water requirements, estimates of presently available supplies, and an assumed distribution of those supplies. Only time will disclose the accuracy of the estimates; however, the reader is reminded that most estimates of this type have proven to be too small.

Pilorcitos Dam in San Mateo County, completed in 1866, created the first reservoir designed to serve San Francisco

City of San Francisca Photograph

Cherry Valley Dam in Tuolumne County, completed in 1956, is the most recent addition to the City of San Francisco's developments

City af San Francisco Photograph

The water problems within the San Francisco Bay Area portion of the North Bay Counties are unlike those in the South Bay Counties. For the most part the development in Marin, Napa, Solano and Sonoma Counties has just begun while in Alameda, Contra Costa, Santa Clara, San Mateo and San Francisco Counties water supplies have already been obtained to permit and sustain a high degree of development. For this reason pertinent data are summarized for the North Bay Counties and the South Bay Counties in the following discussions of the San Francisco Bay Area.

POPULATION

Studies of population, covering all of the San Francisco Bay Counties, except San Benito County, were conducted during the investigation authorized by the Abshire-Kelly Salinity Control Barrier Act of 1953 and are discussed in Appendix A of the March 1955 report. Those studies were conducted on the basis of the probable extremes in population. The high population estimate reflected a high level of economic activity and the low population estimate reflected a low level of economic activity.

Land use patterns, both urban and irrigated agricultural, are related to population. It was, therefore, necessary to develop population projections and the previous estimates of population were used as the starting point of the new study. The objective of the new study was to determine the probable population beginning 1960 and ending in 2010.

The population estimates basic to this study were those developed by the firm of Parsons, Brinckerhoff, Hall and Macdonald during its investigation for the San Francisco Bay Area Rapid Transit Commission. Those estimates were prepared by Mr. Van Beuren Stanbery, a nationally recognized economist and demographer. The basic population estimates were reanalysed and estimates of the probable level of population were developed. The original studies, which ended with year 1990, were extended to year 2010. The resulting estimates of probable future population of the San Francisco Bay Counties are presented in Table 12. These estimates were basic to estimates of the future urban water requirements.

Population estimates of San Benito County were not included in Mr. Stanbery's studies nor were they developed during the current investigation. The majority of the water requirements in San Benito County will be for irrigation of land which overlies a ground water basin. The relatively small quantity of this land which might change from agricultural to municipal uses would not significantly alter the future water requirements of the basin.

LAND USE

Urban land use is related directly to population whereas the irrigated agricultural land use is related indirectly to population, since it must develop on the remaining land. Urban demands for land appear to outrank agricultural demands since a greater monetary value is placed upon the former. Therefore, urban demands would probably predominate if there were conflicts between urban and agricultural uses. Estimates were prepared of the urban land requirements and then the land available for agriculture was determined. The amount of irrigable land which would be irrigated in the future and the probable crop patterns on these lands were also estimated. It was assumed that water would be available at prices which would permit unimpeded development of the land, both for municipal and agricultural purposes.

TABLE 12

POPULATION—1950 TO 2010
SAN FRANCISCO BAY COUNTIES
(In thousands)

County	1950	1960	1970	1980	1990	2000	2010
North Bay Counties							
Marin	85.6	120	170	220	270	310	350
Napa	46.6	70	100	130	170	210	270
Solano	104.8	140	190	250	320	420	550
Sonoma	103.4	140	180	230	290	360	450
Subtotals	340.4	470	640	830	1,050	1,300	1,620
South Bay Counties							
Alameda	740.3	940	1,110	1,280	1,450	1,600	1,710
Contra Costa	299.0	440	600	760	900	1,030	1,150
San Benito	14.4	--	--	Not developed		--	--
San Francisco	775.4	800	820	840	860	880	900
San Mateo	235.7	390	470	540	600	660	720
Santa Clara	290.5	460	610	750	890	1,030	1,150
Subtotals	2,355.3	3,030	3,610	4,170	4,700	5,200	5,630
Totals	2,695.7	3,500	4,250	5,000	5,750	6,500	7,250

San Francisco Bay Area

The future land use patterns in the North Bay Counties involve more uncertainties than those of the South Bay Counties where the patterns have, for the most part, been well established. The growth in the South Bay Counties would not have occurred without adequate water supplies. Since the water plan for the North Bay Counties has been predicated upon an adequate supply of water, it is reasonable to assume that future patterns of land use in the North Bay Counties will be comparable to those in the South Bay Counties.

Urban Land Use. Estimates of future urban land use were developed by application of population density factors to the estimates of future population. The density factors were based upon a composite of all types of urban development, i.e., residential, commercial, industrial, city parks, institutional and streets. Areas with very limited applied water requirements, such as tank farms, arsenals and salt evaporating ponds, were not included. Consideration was given to existing urban patterns and development trends in each county.

The land used for urban purposes in the San Francisco Bay Area would be withdrawn from irrigated, nonirrigated irrigable, or from nonirrigable land. Careful consideration was given to the proportion which would be withdrawn from each of these categories. While it was not possible to develop a detailed pattern of the future urban land use, consideration was given to the probable location of new urban developments and the amount of land taken from the irrigable and nonirrigable classifications. Estimates of population and holding capacities of urban centers, prepared by the planning staff of Parsons, Brinckerhoff, Hall and Macdonald, were also used as guides in distributing the estimated county-wide population to smaller units, and thereby develop a logical distribution of population to various land classes. The estimated urban land use in the San Francisco Bay Area is shown in Table 13.

TABLE 13

URBAN LAND USE—1960-2010
SAN FRANCISCO BAY AREA

(In thousands of acres)

County	1960	1970	1980	1990	2000	2010
North Bay Counties						
Marin	13	19	26	34	40	47
Napa	7	10	14	19	23	30
Solano	10	14	20	27	37	50
Sonoma	8	10	14	18	24	33
Subtotals	38	53	74	98	124	160
South Bay Counties						
Alameda	80	96	113	131	148	162
Contra Costa	42	60	81	102	126	148
San Francisco	26	26	26	26	26	26
San Mateo	51	60	69	78	87	97
Santa Clara	43	59	75	91	107	120
Subtotals	242	301	364	428	494	553
Totals	280	354	438	526	618	713

Agricultural Land Use. For purposes of estimating the amount of new irrigated land, it was assumed that a supply of fresh water would be available by 1960 at a price attractive to the farmer, and that districts would be formed to facilitate financing of distribution and drainage systems. Consideration was also given to such factors as the condition of the soil at various stages of development, the types of crops best-suited to the soils, the payment capacity of the crops, the probable development stage of distribution systems, market conditions, and the probable period available for agricultural endeavors prior to urbanization of the potentially irrigable land. The amount of undeveloped irrigable land in the San Francisco Bay Area portion of the counties in 1949 is presented, by elevation, in Table 14. It is emphasized that not all of this land would be available for new irrigation since some would be withdrawn for urban purposes; some valleys are high in the mountains and could not economically be served irrigation water; and, many small valleys are similarly isolated or occupy long narrow fingers which would involve costly irrigation facilities.

New irrigated acreage in Marin County would probably be limited to land along San Pablo Bay and Petaluma Creek in the vicinity of Novato. Some of the marshland in that vicinity has been reclaimed for dry-farmed agriculture and would be in a position to use water almost as soon as it could be made available. Marin County has a zoning ordinance which precludes development of land below elevation five feet for residential purposes. Since a large portion of the new irrigated acreage would be below this elevation and would require filling to permit subdivision, it was anticipated that some land would remain in agriculture until 2010.

Land which could be irrigated for the first time in the San Francisco Bay Area portion of Sonoma County lies along the eastern side of Petaluma Creek, generally south of its confluence with Adobe Creek, and in the lower reaches of Sonoma Valley.

In Napa County new land could be developed for irrigation in two separate areas, one north and the other south of the City of Napa. Urban development north of Napa would probably preclude irrigated agricultural development within four miles of the present central district, and economic considerations would probably limit irrigation with imported water to land south of Rutherford. The potential areas south of Napa are on both sides of the Napa River and north of the salt evaporating ponds. A limited acreage of irrigated agricultural development might occur

TABLE 14

UNDEVELOPED IRRIGABLE LAND IN 1949
SAN FRANCISCO BAY AREA

(In acres)

County	Elevation, in feet						
	0-50	50-100	100-150	150-250	250-500	Over 500	Total
North Bay Counties							
Marin	15,600	2,400	900	2,400	1,300	200	22,800
Napa	15,700	14,800	10,900	15,600	8,500	3,200	68,700
Solano	73,200	8,400	2,400	900	200	0	85,100
Sonoma	32,300	11,400	7,700	7,400	3,700	200	62,700
Subtotals	136,800	37,000	21,900	26,300	13,700	3,600	239,300
South Bay Counties							
Alameda	21,700	1,600	500	1,400	20,300	20,300	65,800
Contra Costa	6,200	3,700	2,400	3,200	11,200	4,400	31,100
San Francisco	0	0	0	0	0	0	0
San Mateo	2,500	1,400	700	400	1,200	0	6,200
Santa Clara	6,100	900	1,800	3,100	5,200	8,300	25,400
Subtotals	36,500	7,600	5,400	8,100	37,900	33,000	128,500
Totals	173,300	44,600	27,300	34,400	51,600	36,600	367,800

around Suscol Creek. The rapid southward expansion of the City of Napa would probably preclude irrigation of land within three miles of the present central district.

In the portion of Solano County within the San Francisco Bay Area, new irrigated acreage would be expected in the marshland adjacent to Suisun Bay. About 50,000 acres of this land, lying between sea level and five feet in elevation, would be suitable for irrigation, if properly reclaimed. Most of the remaining irrigable land in Solano County, within the San Francisco Bay Area, is in the Solano Irrigation District and will either receive water from the Solano Project or is geographically situated to annex to the Solano Irrigation District.

The majority of the land in Alameda County which would be expected to be irrigated for the first time is located in Livermore Valley. It is expected that irrigation of presently dry-farmed land would take place between Pleasanton and Livermore, and southeast of Livermore. Due to the rapid urbanization of the portion of Alameda County along San Francisco Bay, it is believed that new land would not be brought under irrigation.

A similar situation will arise in Contra Costa County where the urban pressure will be great. Although there is undeveloped irrigable land in Amador Valley, it is anticipated that it will be developed for urban purposes so rapidly that irrigated agricultural development would be uneconomical.

The large areas of irrigated land on both the free ground water zone and pressure ground water zone in Santa Clara Valley necessitate separate consideration of each area. A free ground water zone refers to the portion of a ground water basin not overlain by impervious layers of soil, and where water can percolate directly from the surface into the ground water basin. A pressure ground water zone refers to the portion of a ground water basin overlain by impervious soils which prevent direct percolation into the ground water basin. The pressure zone is supplied with water from the free ground water zone. Applied irrigation water could not percolate into the pressure zone. Therefore, estimates were made of the probable amount of irrigated land on each zone. The 1955 land use plate presented in State Water Resources Board Bulletin No. 7, "Santa Clara Valley Investigation," indicates that about one-third of the urban development between 1948-49 and 1955 was on the free ground water zone while two-thirds was on the pressure zone. It was assumed that the same proportion would occur until 1990. From 1990 to 2010, the distribution between each zone would be equal since the pressure zone would be quite well-developed. Significant amounts of new irrigated land are not anticipated in Santa Clara County.

The undeveloped irrigable land in San Mateo County is largely on the Pacific Ocean slopes in scattered locations and could be economically developed only by small local projects. Therefore, a detailed study was not made of this area. The amount of land presently irrigated which will remain under irrigation in the future, and the amount of land which is not now irrigated but will be irrigated in the future are shown in Table 15. These acreages apply only to the portions of the counties within the San Francisco Bay Area.

A crop pattern was developed for the future acreage of irrigated land to derive the future agricultural water requirements. In areas well-developed for irri-

TABLE 15

PRESENT AND NEW IRRIGATED LAND—1960 TO 2010
SAN FRANCISCO BAY AREA

(In thousands of acres)

County	1960		1970		1980		1990		2000		2010	
	Present	New	Present	New	Present	New	Present	New	Present	New	Present	New
North Bay Counties												
Marin	0.5	2.0	0.3	5.0	0.2	4.2	0.1	3.0	0.1	2.0	0.1	1.0
Napa	2.4	0	2.1	4.0	2.0	6.6	1.9	7.4	1.7	5.6	1.3	3.0
Solano	9.2	0	11.7	10.0	11.7	17.5	9.7	25.0	6.4	31.0	2.2	35.0
Sonoma	1.4	0	1.3	9.0	1.1	18.0	1.0	21.4	0.9	23.4	0.8	22.9
Subtotals	13.5	2.0	15.4	28.0	15.0	46.3	12.7	56.8	9.1	62.0	4.4	61.9
South Bay Counties												
Alameda	21.1	0	12.8	3.0	6.3	8.0	3.3	8.0	0.3	5.0	0.3	2.0
Contra Costa	4.7	0	2.4	0	0.5	0	0	0	0	0	0	0
San Francisco	0	0	0	0	0	0	0	0	0	0	0	0
San Mateo	4.7	0	3.8	0	3.4	0	3.1	0	2.5	0	1.9	0
Santa Clara												
Free ground water zone	57.0	0	53.0	0	49.0	0	45.0	0	40.0	0	35.0	0
Pressure ground water zone	34.0	0	26.0	0	19.0	0	12.0	0	6.0	0	2.0	0
Subtotals	121.5	0	98.0	3.0	78.2	8.0	63.4	8.0	48.8	5.0	39.2	2.0
Totals	135.0	2.0	113.4	31.0	93.2	54.3	76.1	64.8	57.9	67.0	43.6	63.9

gation, patterns have been generally established and these patterns were assumed to continue during the next 50 years. The projected crop patterns included consideration of established patterns, patterns in comparable areas, urban competition for land which would induce higher value crops, and the sequence of crops which might be necessary to bring virgin land into full production. The yields and net returns of various crops were considered and, in cases where physical conditions would permit alternative crops, those with the highest net return were assumed to occupy the land.

North Coastal Area

The trend of land use patterns is not fixed in the portions of Marin and Sonoma Counties within the North Coastal Area. It is expected that only limited urban and irrigated agricultural development will occur in Marin County during the 50-year period. However, a significant development is expected in Sonoma County.

Urban Land Use. The total urban land requirements in Sonoma County in 2010 will probably not exceed 20,000 acres, and a large portion of the urban development will occur on nonirrigable land. There is a large amount of undeveloped irrigable land in Sonoma County and, therefore, urban land use will have little influence on the development of irrigated agriculture.

Agricultural Land Use. There are only negligible areas of irrigated agriculture in Marin County. These areas are relatively small and widely scattered along numerous creeks. The productivity of these lands is limited by climatic conditions and, therefore, even with a firm water supply, their payment capacity would be low. The scattered location of the areas would involve excessive costs for development of either imported or local water resources. For these reasons, reportable acreages of newly irrigated land are not expected in the portion of Marin County in the North Coastal Area.

Although the ultimate net irrigable area in the portion of Sonoma County in the North Coastal Area, as shown in State Water Resources Board Bulletin No. 2, is about 190,000 acres, the development during the 1960-2010 period will depend somewhat upon the price of water available for agricultural uses. The most favorably located lands, with respect to large scale irrigation development, are on the Santa Rosa Plains and along the Russian River and Dry Creek. A large portion of the irrigable land is in isolated valleys and on rolling land amenable only to sprinkler irrigation.

The Whipple Engineering Company, Consulting Engineers of Palo Alto, California, prepared a report for the Sonoma County Flood Control and Water Conservation District in 1950. That report included an intensive analysis of agricultural development in Sonoma County and was used in estimating the future irrigated agricultural development in the portion of Sonoma County in the North Coastal Area. The estimates prepared by Whipple Engineering Company were also used by the United States Corps of Engineers in its study of the Coyote Valley Project. The estimated future irrigated acreage in this area is shown in Table 16.

TABLE 16

ESTIMATED IRRIGATED ACREAGE IN SONOMA COUNTY, NORTH COASTAL AREA

(In acres)

Year	Amount
1960	13,800
1970	19,200
1980	24,700
1990	30,200
2000	35,700
2010	40,600

Central Valley Area

Portions of Napa, Solano, Contra Costa, Alameda and San Benito Counties lie within the Central Valley Area. The section of Napa County in this area is in the upper Putah Creek drainage basin. Extensive urban development is not anticipated in this area and the irrigable land lies in small scattered valleys which can be developed most readily from limited local water supplies.

The small portion of Alameda County in the Central Valley Area lies on the eastern slope of the Coast Ranges. There would be only limited, if any, urban development in this section during the 1960-2010 period. Urban development in the portion of San Benito County in the Central Valley Area is also not anticipated, and irrigated agricultural development will probably be limited to local water supplies. Large scale development will be dependent upon imported supplies from the Central Valley, and, as the irrigable area lies between 1,000 and 1,500 feet in elevation, this will probably not occur during the period under study.

Urban Land Use. It is estimated that about 10,000 acres of land will be required for urban purposes in Solano County. The majority of this development will occur on irrigated land which will result in little change in over-all water requirement.

A detailed analysis of the future urban land use was not made for the portion of Contra Costa County in the Central Valley Area since (1) the areas considered susceptible to urban development during the next 50 years can be served water from the Contra Costa Canal or from facilities of the East Contra Costa or Byron-Bethany Irrigation Districts, and (2) a change from irrigated agriculture to urban land use usually results in little change in over-all water requirement. Industries which require large quantities of water will probably continue to locate along the northeast fringe of the county and receive water from either the Contra Costa Canal or from the San Joaquin River.

Agricultural Land Use. A large portion of the irrigable land in the Central Valley Area portion of Solano County is contained within the Solano Irrigation District which is shown on Plate 9. This area will be served supplemental water from the Solano Project. There is also a relatively large area between the Solano Irrigation District and the areas presently served by diversions from the Delta. This land is in a position to very easily receive water from the Solano Project and was considered by the United States Bureau of Reclamation in its planning of the project.

The Solano Project is under construction and will supply water in conjunction with local ground water supplies to meet the requirements of the Solano Irrigation District. Therefore, the District will not need additional supplemental water during the study period. In the portion of the county outside of the district, the better irrigable land is adjacent to the Delta and is presently irrigated by direct diversion. There are also some poorer irrigable lands, with heavy soils, which lie between the probable service area of the Solano Project and the Delta. The Maine Pairie Water Association, Inc. was created in 1956 to develop about 7,500 acres of this land from Delta water supplies. Further development of this area, by diversion from the Delta, will probably occur.

Most of the irrigable land in Contra Costa County is presently irrigated in the districts shown on Plate 9. The undeveloped irrigable land is in long, narrow valleys adjacent to the existing districts and at higher elevations. If these areas are developed for irrigation, they would probably be annexed to the existing districts.

As in Contra Costa County, the majority of irrigable land in Alameda County in the Central Valley Area which is economically feasible for development is presently irrigated. This land is within the Byron-Bethany Irrigation District.

Central Coastal Area

Portions of Santa Clara and San Benito Counties lie within the Central Coastal Area. A large section of San Benito County lies in the upper watershed of the San Benito River. The irrigable land is in scattered valleys at relatively high elevations and irrigated agricultural development will be dependent upon local water resources. The studies on San Benito County have been devoted principally to the areas around Hollister and in the San Juan Valley.

Urban Land Use. The future water requirements of the portion of Santa Clara County in the Central Coastal Area may be considered on an area-wide basis since (1) the urban land use will be relatively small compared to the irrigated land use in 2010 (about 5,000 acres compared to about 45,000 acres, respectively), and (2) urban development will be largely on

land presently irrigated and will, therefore, have only a slight effect on water requirements. Therefore, detailed estimates were not made of the urban land requirements.

The future urban land requirements in San Benito County will have little bearing on the future water requirements of the area since the population growth will be nominal. Therefore, estimates were not prepared of urban land requirements of San Benito County.

Agricultural Land Use. The irrigable land in Santa Clara County in the Central Coastal Area is largely developed for irrigation at the present time. The South Santa Clara Valley Water Conservation District includes this area and is actively developing local water resources to meet the local water requirements.

The irrigable land in San Benito County is located principally around Hollister and in the San Juan Valley at the lower end of the San Benito River. The United States Bureau of Reclamation conducted an investigation of the Hollister area including San Juan Valley in 1950-53. It was concluded that the productive land in the area is about 53,000 acres, excluding farmsteads and roads, of which about 49,300 acres would be irrigated in any one year under full development. About 32,400 acres are presently irrigated from ground water supplies but do not receive sufficient water for optimum crop yields. An estimate of the future irrigated acreage was not made by decades.

WATER REQUIREMENTS

Water requirements, as the term is used in this bulletin, are the amounts of water which must be supplied in addition to precipitation to provide for all beneficial uses and for irrecoverable losses incidental to such uses.

San Francisco Bay Area

The studies of water requirements of the San Francisco Bay Area were based upon the detailed studies on population and land use.

Urban Water Requirements. The urban water requirements of the San Francisco Bay Area were estimated through use of the population-water factor method. In this method, the required urban water delivery is determined by applying a per capita water use factor to the population. In preparation of State Water Resources Board Bulletin No. 2, "Water Utilization and Requirements of California," factors of urban water utilization were estimated for conditions of ultimate development by considering present trends and estimating the effects of changing land use patterns. The urban water requirement factors were developed for areas of like climatic conditions and not necessarily on a county-wide basis. These requirements would be measured at the consumer's meter. An additional 10 per cent would be required at the point of diversion to attain this delivery.

In the current study, the ultimate water use factors developed for State Water Resources Board Bulletin No. 2 were used for the year 2010; factors for intermediate years were obtained by straight line interpolation. Factors were developed for the North Bay Counties for 1970 after considering estimates of industrial development for that year, and factors for intermediate years were obtained by straight line interpolation between 1950 and 1970, and between 1970 and the ultimate factors used for 2010.

The estimated urban water requirements are presented by the portions of counties within the San Francisco Bay Area in Table 17. These estimates include allowances for distribution losses.

TABLE 17

ESTIMATED URBAN WATER REQUIREMENTS SAN FRANCISCO BAY AREA

(In thousands of acre-feet)

County	1960	1970	1980	1990	2000	2010
North Bay Counties						
Marin	16	24	33	43	53	63
Napa	12	17	23	31	39	52
Solano	20	28	39	50	66	88
Sonoma	7	11	17	25	35	49
Subtotals	55	80	112	149	193	252
South Bay Counties						
Alameda	135	164	198	231	264	289
Contra Costa	138	178	209	234	254	267
San Francisco	89	92	95	98	102	105
San Mateo	64	79	93	105	117	131
Santa Clara	78	105	132	159	186	210
Subtotals	504	618	727	827	923	1,002
Totals	559	698	839	976	1,116	1,254

Irrigation Water Requirements. Future irrigation water requirements were estimated by computing the consumptive use of the various crops utilizing the Blaney-Criddle method. This method gives consideration to the length of growing season, the thermal units and the effective precipitation for each crop. Consumptive use coefficients have been developed by the authors through experimentation. Future irrigation water deliveries were then obtained by applying consumptive use factors to the estimated acreage of various crops grown on the future irrigated land and using an irrigation efficiency of 60 per cent. On land overlying free ground water zones, it was assumed 30 per cent would percolate to ground water, and 10 per cent would be irrecoverably lost.

In Livermore and Santa Clara Valleys consideration was given to the application of water to lands overlying free ground water zones, and 30 per cent was assumed to be available for reuse. Based upon data presented in Bulletin 7, an irrigation efficiency

of 85 percent was considered in the extensive pressure zone in Santa Clara Valley. It was assumed that the remaining 15 per cent would not be available for reuse. Similar consideration was given to the pressure zone in Livermore Valley. Due to the limited extent of the free ground water zone along the bayside of Alameda County, reuse of return water was not considered.

The estimated future irrigation water requirements within the San Francisco Bay Area portion of the counties are presented in Table 18. The decrease in requirements after 1980 reflects the changeover from irrigation to urban land use.

TABLE 18

ESTIMATED IRRIGATION WATER REQUIREMENTS SAN FRANCISCO BAY AREA

(In thousands of acre-feet)

County	1960	1970	1980	1990	2000	2010
North Bay Counties						
Marin	8	16	13	9	6	3
Napa	5	17	24	26	20	11
Solano	25	67	91	109	116	113
Sonoma	4	31	57	65	69	66
Subtotals	42	131	185	209	211	193
South Bay Counties						
Alameda	47	34	30	25	12	5
Contra Costa	13	7	2	0	0	0
San Francisco	0	0	0	0	0	0
San Mateo	8	6	6	5	4	3
Santa Clara						
Free ground water zone	146	136	125	114	101	88
Pressure ground water zone	56	43	31	20	9	3
Subtotals	270	226	194	164	126	99
Totals	312	357	379	373	337	292

North Coastal Area

As described in the foregoing sections, significant urban and irrigated agricultural land use will develop only in Sonoma County. The urban water requirements were related to the portion of the population previously described which would settle in the area. Per capita water requirement factors, with an allowance of 10 per cent for distribution system losses, were applied to the population estimates. The future irrigation water requirements were based upon studies made by Whipple Engineering Company. The estimated urban and irrigation water requirements of Sonoma County within the North Coastal Area, are presented in Table 19.

TABLE 19

ESTIMATED URBAN AND IRRIGATION WATER REQUIREMENTS IN SONOMA COUNTY NORTH COASTAL AREA

(In acre-feet)

Year	Urban	Irrigation
1960	11,000	28,000
1970	14,000	38,000
1980	18,000	48,000
1990	23,000	57,000
2000	28,000	67,000
2010	33,000	75,000

Central Valley Area

Water for the portions of the San Francisco Bay Counties within the Central Valley Area will be required mainly in Solano and Contra Costa Counties. Limited local supplies will be utilized in Napa and San Benito Counties and in Alameda County water will be diverted from the Delta.

Urban Water Requirements. The future urban water requirements within Solano County will be largely within the service area of the Solano Project. Rio Vista, on the Sacramento River, would be an exception. The annual urban water requirements will increase from about 3,000 acre-feet at present to about 20,000 acre-feet in year 2010. The Solano Project and local ground water resources will provide sufficient water to meet these requirements.

The urban requirements in Contra Costa County will also be largely within organized water service agencies which will be able to meet the demands. A large portion of the requirements will be for industrial purposes which will probably be met by direct diversion from the San Joaquin River. Detailed estimates of the total requirements were not made due to the location of the county with respect to available supplies.

Irrigation Water Requirements. The water requirements of most of the irrigable land in Solano County can be met from ground water, the Solano Project, and direct diversions from the Delta. Further development of irrigable land can be accomplished by additional diversions from the Delta of water made available by the Central Valley Project or the Feather River Project. Detailed estimates were not made of the water requirements of Solano County.

The irrigable areas in Contra Costa and Alameda Counties are largely developed with supplies diverted from the Delta. Extension of the irrigated acreage, if any, can be developed with water from the same source. Therefore, the water requirements of the area were not computed.

Central Coastal Area

Detailed studies were not made for the urban water requirements of the portions of Santa Clara and San Benito Counties within the Central Coastal Area since the relatively small urban development would occur on irrigated land and the effect on total water requirements would be minor.

Santa Clara County is almost wholly developed for irrigated agriculture. Only limited areas of dry-farmed land are scattered throughout the irrigated area. Data presented in State Water Resources Board Bulletin No. 7 indicate that local water supplies are adequate to meet the ultimate requirements.

In the studies of the Hollister area of San Benito County, conducted by the United States Bureau of Reclamation, it was concluded that the land presently under irrigation, 32,400 acres, would require about 62,000 acre-feet annually for optimum crop yields. About 52,000 acre-feet are presently being applied. It was estimated that the area would require about 100,000 acre-feet annually under full development.

WATER SUPPLIES

To determine the supplemental water requirement, i.e., the amount of water needed in addition to presently available supplies, it was necessary to evaluate the yields of present and foreseeable water supplies. It was also necessary to assume a distribution of those yields to potential service areas.

As used in this study, yield is synonymous with safe yield and is defined as follows: Yield is the amount of water which can be obtained annually from a given source under stated conditions of construction, or other limiting factors without a deficiency in any year.

San Francisco Bay Area

To facilitate presentation, the water supplies of the San Francisco Bay Area were considered as local supplies and imported supplies. The local supplies would be utilized principally within the county in which they exist while imported supplies might be utilized in more than one county.

Local Water Supplies. The estimated yields of local supplies were obtained from data developed for State Water Resources Board Bulletin No. 2, and are limited to works constructed to 1955. The studies of surface supplies considered the monthly demand schedule for intended uses and losses due to evaporation. The local yields were measured at the reservoirs, and do not reflect limitations which might be imposed by presently constructed conveyance works. The water supply available to surface storage reservoirs was determined from stream flow records, or estimated by means of correlation with records of streams having similar runoff characteristics. Yields of ground water basins were based upon the best available information at this date.

The local surface water supplies within the San Francisco Bay Area would be utilized almost entirely for urban purposes. The ground water supplies, including water from those basins operated conjunctively with surface reservoirs, were assumed to be available for irrigation purposes and when not any longer required for this use, would be available for urban purposes. There has been a tendency to abandon ground water supplies in favor of surface supplies for urban purposes. This has occurred in San Francisco and in other localities of the Bay Area where the yield from ground water sources was limited. It was assumed that not more than 6,000 acre-feet from ground water in Solano County would be utilized for urban purposes when not required for irrigation purposes, and in San Mateo County 4,000 acre-feet of the ground water supplies would not be used for urban purposes when not required for agricultural purposes. The local water supplies would be used within the county in which they exist, except for the yield of Calaveras Reservoir in Alameda County which is owned and operated by the San Francisco Water Department. The yield of this reservoir would be distributed by the San Francisco Water Department. The estimated firm annual yields of the local water supplies within the portions of the Bay Counties in the San Francisco Bay Area are presented in Table 20.

TABLE 20

LOCAL WATER SUPPLIES
SAN FRANCISCO BAY AREA

(In acre-feet)

County	Surface supplies	Underground supplies	Total
Marin	19,000	minor	19,000
Sonoma	2,000	4,000	6,000
Napa	16,000	6,000	22,000
Solano	5,000	8,000	13,000
Alameda			
Livermore Valley	[1]32,000	17,000	49,000
Bayside	12,000	31,000	43,000
Contra Costa	8,000	8,000	16,000
Santa Clara	(combined)		175,000
San Mateo			
Bayside	11,000	13,000	24,000
Coastal	3,500	12,500	16,000
San Francisco	(combined)		11,000

[1] Yield of Calaveras Reservoir which is owned and operated by the San Francisco Water Department.

Imported Water Supplies. Unlike the South Bay Counties, the North Bay Counties have only recently looked to outside areas for imported water supplies. The potential yields of the importation works, shown on Plate 9, were assumed to be restricted to the conditions set forth in applications to the State of California for water rights or to estimates of yields prepared by the constructing agency.

The City of Vallejo has a permit from the State Water Rights Board to divert a constant flow of 31.52 second-feet from Cache Slough. This is equivalent to approximately 23,000 acre-feet per year which was taken as the yield of the system. It was assumed that the portion of this supply not required by Vallejo would be available for distribution in southern Napa

County. Approximately 9,600 acre-feet of water were diverted from Cache Slough during 1956.

The United States Bureau of Reclamation is presently constructing Monticello Dam across Putah Creek west of the town of Winters. This dam, together with its appurtenant features, is officially entitled the Solano Project. The Bureau of Reclamation has estimated that this project will be completed in 1958 and will yield 216,000 acre-feet of water for agricultural uses, and 31,000 acre-feet of water for municipal and industrial uses. The proposed service area of the Solano Project lies entirely within Solano County, extending from north of Dixon to west of Cordelia. Therefore, only a portion of the service area lies within the San Francisco Bay Area. It was estimated that about 55,000 acre-feet will be required in the San Francisco Bay Area. The City of Vallejo has contracted for 15,000 acre-feet of water, and a portion of the quantity not required by the City would be available for distribution in southern Napa County. Of the remaining 40,000 acre-feet available to the San Francisco Bay Area, up to 25,000 acre-feet would be available for irrigation uses and the remainder for urban uses. As urban development replaces irrigation development, the irrigation supplies were assumed to become available for urban purposes. It was further assumed that Solano Project water would not be available for irrigation use outside of the Solano Irrigation District.

The South Bay Counties presently import water from the Central Valley Area through three major systems: (1) the Contra Costa Canal, diverting from the Delta; (2) the Mokelumne River system of the East Bay Municipal Utility District; and, (3) Hetch Hetchy system of the City of San Francisco. The amounts of water which can be depended upon from these projects, and certain limitations placed thereon, are described in the following paragraphs.

The Contra Costa Canal was built with a capacity of 350 second-feet at the point of diversion by the United States Bureau of Reclamation as a feature of the Central Valley Project. The capacity is presently limited by installed pump facilities to 310 second-feet at that point. The canal has a capacity of only 269 second-feet where it enters the San Francisco Bay Area. Studies were made to determine the amount of water which might be available to the Bay Area through this canal, including pumping facilities with ultimate capacity, but not including additional regulatory storage. This study indicated that 146,000 acre-feet of water could be imported annually to the San Francisco Bay Area and would be distributed by the Contra Costa County Water District. This amount was taken as the yield of the canal as it relates to the San Francisco Bay Area. In 1956, approximately 46,200 acre-feet of water were diverted into the canal at Pumping Plant No. 1.

The East Bay Municipal Utility District has developed the Mokelumne River under terms of a permit from the State Water Rights Board for diversion of 224,000 acre-feet of water per year (200 M.G.D.) to its service area as shown on Plate 9. All of the storage works necessary to develop this water have been constructed and present conveyance works are capable of delivering the entire amount. Approximately 122,000 acre-feet of water were imported to the San Francisco Bay Area through the Mokelumne Aqueduct during 1955. The District has recently been granted a permit for an additional 140,000 acre-feet of water. Since the District has always increased the size of its conveyance system to keep pace with demands, the dependable yield of the Mokelumne River system is considered to be 364,000 acre-feet of water per year. This system would supply water to meet the requirements, in excess of the yield of local supplies within the service area of the district.

The City of San Francisco claims a right to in excess of 448,000 acre-feet of water per year (400 M.G.D.) from the Tuolumne River. The claim of the City of San Francisco is based upon water rights filed prior to the Water Commission Act and, therefore, the place of intended use is not specifically defined. The City proposes to import at least 448,000 acre-feet to the San Francisco Bay Area through an expanded Hetch Hetchy system. At the present time, neither the storage reservoirs nor the conveyance system is capable of importing more than about 157,000 acre-feet of water per year; the maximum importation to date was 123,000 acre-feet, made during the 1954-55 water year. A yield of at least 448,000 acre-feet of water can be developed if the City of San Francisco carries its present plans to conclusion. This supply would be available to meet the urban requirements as the Raker Act prohibits its use for irrigation purposes. It is anticipated that this supply would be used to supplement the local supplies in San Francisco and San Mateo Counties.. In addition, the City of San Francisco has stated its willingness to supply supplemental water in northern Santa Clara Valley and in the southern bayside portion of Alameda County. Local interests in these two areas have not yet specifically indicated whether they desire water from this source and, therefore, it is not possible to specify the amounts of water which will be furnished.

The State Legislature has authorized the Alameda-Contra Costa-Santa Clara-San Benito Branch of the Feather River Project Aqueduct as a feature of The California Water Plan and has also provided funds for plans and specifications. This branch, which is referred to herein as the South Bay Aqueduct, would import water from the Central Valley to serve the supplemental water requirements in Contra Costa, Alameda, Santa Clara and San Benito Counties. The magnitude of the supplemental requirements in these

Monticello Dam during construction

U. S. Bureau of Reclamation Photograph

Putah South Canal

U. S. Bureau of Reclamation Photograph

counties is currently being studied in cooperation with local water service agencies. In Alameda and Santa Clara Counties the requirements will be dependent upon the amount of water supplied by the San Francisco Water Department, and the desires of the local agencies have not been fully expressed on this matter. When the demands from the South Bay Aqueduct have been determined, the aqueduct will be designed to meet these demands.

North Coastal Area

The description of water supplies in the portions of the San Francisco Bay Counties lying in the North Coastal Area is limited to Sonoma County, since the requirements in Marin County will be relatively small and will be met from local sources.

Local Water Supplies. In studies by the United States Corps of Engineers for the Coyote Valley Project, the annual yield of local sources in Sonoma County was estimated at 44,000 acre-feet. The annual yield of sources within the San Francisco Bay Area has been estimated at about 6,000 acre-feet indicating a supply of 38,000 acre-feet in the portion of Sonoma County in the North Coastal Area. This supply is mainly from ground water and was considered as a portion of the total supply to be utilized for urban and irrigation purposes.

Imported Water Supplies. The Coyote Valley Project is presently being constructed by the United States Corps of Engineers on the East Fork of the Russian River in Mendocino County. In addition to flood control, this project will produce a firm annual conservation yield of 60,000 acre-feet of which 5,000 acre-feet will be available to Mendocino County, and 55,000 acre-feet to Sonoma County which will be available for urban and irrigation uses.

Water will be released from the reservoir into the Russian River and will be directed into main conveyance systems for transmission to service areas. Bonds are available to the Sonoma County Flood Control and Water Conservation District for construction of the main conveyance systems. These works will be constructed by the District when local agencies have contracted with the District for water to assure financial feasibility of the facilities.

An estimate of the distribution of local and imported supplies in Sonoma County was not attempted. The ground water supplies will probably be utilized primarily for irrigation. In 1950, about 19,000 acre-feet were used for irrigation, and 7,200 acre-feet were used for urban purposes. The proposed conveyance systems from the Russian River will be used for both irrigation and urban purposes. The total annual supply in Sonoma County, 93,000 acre-feet, including the yield from the Coyote Valley Project, would be available for all purposes within the portion of Sonoma County in the North Coastal Area.

Central Valley Area

Portions of two counties, Napa and San Benito County, within the Central Valley Area have limited water supplies, while portions of Solano and Contra Costa County have ample supplies at the present time and are in an ideal position for further diversion from the Delta.

Local Water Supplies. Present local water developments in Napa County are limited to small diversions from local streams. The combined yields from these sources are considered to be less than 1,000 acre-feet per year.

Water is available in Solano County from the Solano Project, ground water basins, and from the Delta. It is estimated that about 190,000 acre-feet will be available to the portion of Solano County in the Central Valley Area from the Solano Project. Under present operation practices, the diversions from the Delta for irrigation are relatively large, reflecting low pumping costs. This water is obtained from the Sacramento River.

Water is diverted from the Delta for irrigation of the portions of Contra Costa and Alameda Counties in the Central Valley Area. These supplies are used in conjunction with local ground water supplies. Data are not available on the quantities utilized from each source. The supplies are considered adequate to meet the requirements.

Ground water is available in limited quantities in Panoche Valley in San Benito County.

Imported Water Supplies. Although the intake of the Contra Costa Canal is located in Contra Costa County, it is an import system since the source of supply is from Central Valley Project storage facilities located in the Sacramento Valley. The yield of the Contra Costa Canal available to the portion of Contra Costa County within the Central Valley Area is dependent upon the demand schedules of the diverters. The demand schedules would be quite uniform since the water would be used primarily for industrial and municipal purposes. However, detailed schedules were not developed.

Central Coastal Area

Development in the portions of Santa Clara and San Benito Counties within the Central Coastal Area has thus far been limited to local supplies. The local supplies in Santa Clara County, when developed, will be adequate to meet the future water requirements while San Benito County will require imported supplemental water.

Local Water Supplies. The water supplies of Santa Clara County are described in detail in State Water Resources Board Bulletin No. 7. The yield of the ground water basin is about 45,000 acre-feet, including 5,700 acre-feet from conjunctive operation of Chesbro Reservoir on Llagas Creek. The South Santa Clara Valley Water Conservation District is currently constructing a dam and reservoir on Uvas Creek with storage capacity of 10,000 acre-feet. This reservoir and the pipeline to percolation areas on Llagas Creek will yield about 10,000 acre-feet annually, if operated in conjunction with Chesbro Reservoir. The yield of the project could be increased to 16,300 acre-feet by enlarging the reservoir to 34,000 acre-feet of storage capacity. The present safe annual supply is 55,000 acre-feet, and this could be increased to about 61,000 acre-feet.

The Hollister Irrigation District and the Pacheco Pass Water District in the Hollister area have constructed works for supplementing the natural ground water recharge. These districts are shown on Plate 9. The Hollister Irrigation District has a diversion dam on the San Benito River which diverts water to the Paicines Reservoir which has a storage capacity of 3,000 acre-feet. The yield of this project is less than 1,000 acre-feet. The Pacheco Pass Water District operates the North Fork Reservoir which has a storage capacity of 6,000 acre-feet, for regulating flows for ground water recharge along Pacheco Creek. It is estimated that the increase in percolation due to releases from this reservoir has averaged 2,700 acre-feet annually. The safe annual yield of the ground water basin is 45,000 acre-feet, including the supplemental recharge from the above works. This yield was assumed to be available for both urban and irrigation purposes.

The City of Hollister annually pumps about 400 acre-feet of ground water from Cienega Valley and conveys this water by pipeline to the city. Cienega Valley is located about six miles south of Hollister and is within the San Benito River Basin. Hollister is also supplied with about 400 acre-feet annually from the local ground water basin.

It was estimated by the United States Bureau of Reclamation that 47,000 acre-feet of the average annual runoff of San Benito River, Tres Pinos and Pacheco Creeks do not contribute to the present supply of the Hollister area. This water could be considered for future development. Projects on San Benito River and Pacheco Creek studied by the Bureau of Reclamation would have a firm annual yield of about 14,000 acre-feet.

In addition to providing water within the San Francisco Bay Area, the South Bay Aqueduct would supply water to San Benito County. Studies are being conducted by local agencies to determine their estimates of water requirements from the aqueduct.

SUPPLEMENTAL WATER REQUIREMENTS

Supplemental water requirements are defined herein as the difference between water requirements and available supplies.

San Francisco Bay Area

The supplemental urban and irrigation water requirements of the portions of the North Bay Counties within the San Francisco Bay Area are shown in Table 21. As previously discussed, the South Bay Aqueduct of the authorized Feather River Project would be designed to meet the requirements of Livermore Valley in Alameda and Contra Costa Counties, the southern bayside portion of Alameda County and northern Santa Clara County which would not be met by local supplies or purchases from the San Francisco Water Department. Therefore, estimates of the supplemental water requirements only in the North Bay Counties within the San Francisco Bay Area are included in Table 21.

North Coastal Area

The supplemental water requirements of the portion of Sonoma County within the North Coastal Area are shown in Table 22.

TABLE 21

ESTIMATED SUPPLEMENTAL WATER REQUIREMENTS
SAN FRANCISCO BAY AREA
(In thousands of acre-feet)

County	1960		1970		1980		1990		2000		2010	
	Urban	Irrigation	Urban	Irrigation	Urban	Irrigation	Urban	Irrigation	Urban	Irrigation	Urban	Irrigation
Marin	0	8	5	16	14	13	24	9	34	6	44	3
Napa	0	0	0	11	0	18	0	20	8	14	23	5
Solano	0	0	0	34	0	58	4	81	9	97	18	106
Sonoma	5	0	9	27	15	53	23	61	33	65	47	62
Totals	5	8	14	88	29	142	51	171	84	182	132	176

TABLE 22

ESTIMATED SUPPLEMENTAL WATER REQUIREMENTS
SONOMA COUNTY, NORTH COASTAL AREA

(In acre-feet)

Year	Amount
1960	0
1970	0
1980	0
1990	0
2000	2,000
2010	15,000

Central Valley Area

Based upon the analyses previously described, the portions of the counties within the Central Valley Area would not have water requirements beyond the capacity of the present sources of supply.

Central Coastal Area

The portion of Santa Clara County within the Central Coastal Area has local supplies which, if fully developed, would be sufficient to meet the ultimate requirements of the area.

The portion of San Benito County within the Central Coastal Area will require imported water from the South Bay Aqueduct. Under present conditions, the average annual overdraft on the ground water basin in the Hollister area is about 7,000 acre-feet. About 10,000 acre-feet annually could be beneficially used to produce optimum yields on presently irrigated land. The supplemental requirement to meet full development is about 55,000 acre-feet annually. An annual yield of about 14,000 acre-feet from local supplies could be developed. The cost, however, would be about the same as the cost of imported water and would supply only a portion of existing deficiencies. It appears reasonable to consider importation of about 40,000 acre-feet annually at this time, and when this supply is fully utilized, give further consideration to development of local supplies or additional imports. It is believed that the use of an imported supply would increase to about 20,000 acre-feet per year 10 years after the initial delivery, to about 30,000 acre-feet per year after 20 years, and to 40,000 acre-feet per year by the end of 30 years.

WATER PLAN

The San Francisco Bay System creates a natural division between the North Bay Counties and the South Bay Counties. From the viewpoint of water requirements there is also a division between the North Bay Counties and the South Bay Counties. The development in the North Bay Counties is only starting as compared to the South Bay Counties. The existing local water supplies in all of the counties have largely been developed, and major import systems have been constructed and authorized for the South Bay Counties. To permit continued development in the North Bay Counties, it will be necessary to provide imported water.

North Bay Counties Water Plan

In formulating a plan capable of developing and delivering sufficient water to meet the future demands of the North Bay Counties, it was necessary to consider not only the quantities of water which would be required, but also the location of those requirements and the purpose for which the water would be used. It was found that entirely different conclusions could be drawn if plans were developed upon different assumptions. Recognizing the importance of the basic assumptions, those used in developing the North Bay Counties Water Plan are restated below:

1. Plan for 1960-2010 period.
2. Provide for both urban and irrigation demands.
3. Protection to areas of origin.
4. Supplement existing facilities.
5. Need must be demonstrated.
6. Works are to be economically justified and financially feasible.
7. Desire for plan must be demonstrated.

The influence of these assumptions will be apparent in the planning described in the following sections.

It has been pointed out that supplemental water will be required at an early date to meet the rapid growth in those portions of Marin, Sonoma, Napa and Solano Counties which drain directly to Suisun and San Pablo Bays. Nearly all additional development in Petaluma and Sonoma Valleys, both municipal and agricultural, must be supplied with imported water. Without these supplies, the standstill, which development in the area appears to have reached, will continue.

The California Water Plan. The California Water Plan provides a means of conserving and conveying sufficient water to meet the demands of all areas of the State under ultimate conditions of development. Under The Plan, this water would be provided by both local and import systems.

The California Water Plan was designed as a long-ranged solution to water problems throughout California. The Plan, as presented in State Water Resources Board Bulletin No. 3, is intended to serve as a guide in selecting future water resources developments, and is designed so that future projects will fit into a logical pattern which will work for the benefit of all areas of the State. The California Water Plan is not a construction proposal, nor is it a hard and fast listing of individual projects which will be constructed at some future date. Before a unit of The

Plan could actually be proposed as a project for construction, detailed studies would be required, including the impact of projects on local areas, water rights, and all other matters affecting feasibility.

The California Water Plan includes provisions for supplying water to the North Bay Counties through the development of runoff from local streams, and by importing water from the Eel River, from Putah Creek, and from the Sacramento-San Joaquin Delta. Both local and import projects were considered in developing a North Bay Counties Water Plan which would be economically warranted during the next 50 years.

Eel River projects include provisions for bringing additional water from the Eel River into the Russian River Basin and into the Putah Creek Basin. These projects were found to be too large and too expensive for consideration for the North Bay Counties alone. Insufficient data exist regarding the times and quantities of water needed elsewhere in the State to be assured of state-wide justification of these projects soon enough to provide the water needed for the North Bay Counties in the very near future.

Nearly all of the water of the Putah Creek Basin has been assigned to the Solano Project, or to users within the drainage basin, by the State Water Rights Board. Before plans can be developed for exporting water from that basin, a means must be found of augmenting the natural supply. Under The California Water Plan, this would be accomplished by transferring Eel River water through the Cache Creek Basin into the Putah Creek Basin. Therefore, the conclusion that Eel River supplies could not be depended upon during the 1960-2010 period precluded consideration of bringing water into Napa Valley from the Putah Creek Basin. This conclusion also raised doubts as to the desirability of exporting water from the Russian River Basin when it has been shown that an amount of water nearly equal to that which can be developed by all features of The California Water Plan in the Russian River Basin will be required to meet the ultimate demands, 311,000 acre-feet, within that area of origin. Studies of the cost of importing Russian River water to meet the supplemental water requirements of the portions of Marin, Sonoma and Napa Counties within the San Francisco Bay Area, indicated that the water would be more expensive than water imported from the Sacramento River. The North Bay Counties Water Plan was, therefore, developed primarily around local projects and an import system from the Central Valley Area.

Plans for Local Water Resources Development. The California Water Plan proved to be a valuable guide in selecting projects which might be suited to serving water in localized areas. The Upper Napa Valley is such an area. Because of its long, narrow shape, works designed to convey water up Napa Valley would be expensive per unit of water delivered. It would, therefore, be advantageous to develop water within the valley for its use. Three possible projects are listed in The California Water Plan for conservation of water resources in Napa Valley. These projects are Wing Canyon on Dry Creek, Sulphur Springs on Sulphur Creek, and Spring Valley an offstream-pump-storage project near St. Helena. Of these three projects, the Spring Valley Project appears to be the most feasible.

The Spring Valley Project would include a diversion structure across the Napa River and pumping facilities to divert winter flows into a reservoir created in the adjacent Spring Valley. The reservoir would have a storage capacity of 7,000 acre-feet and would be created by construction of three earthfill dams with crests at an elevation of 276 feet. The highest dam would be 86 feet above natural ground. The main dams would have a total length of 1,660 feet and one saddle dam 10 feet in height would be required.

Topographic surveys were made of the dam and reservoir sites. The area and capacity of the reservoir determined from these surveys are presented in Table 23.

TABLE 23

AREAS AND CAPACITIES OF SPRING VALLEY RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
10	200	19	------
20	210	44	310
30	220	71	890
40	230	104	1,760
50	240	126	2,910
60	250	146	4,270
70	260	163	5,810
80	270	181	7,530
90	280	197	9,420
100	290	213	11,470

The site was found to be geologically satisfactory for earthfill dams up to 100 feet in height. There is only minor seismic activity in the general region. The sites would require about 15 to 20 feet of stripping under the impervious zones of the dams and about 10 feet under the pervious zones. Materials for the dams are available within the reservoir area. It is believed that there would be very little leakage from the reservoir.

A pumping plant with capacity for 40 second-feet would be located along the river at a low diversion dam. A minimum flow of 10 second-feet would be permitted to pass the diversion dam and flows in excess of this minimum release would be available for diversion. Water from this project would be released back

into the Napa River and conveyed to downstream diverters.

This project would develop water for irrigation in the upper portion of Napa Valley more economically than an imported water supply. The yield of the project would be about 5,400 acre-feet per year, if a deficiency of 35 per cent is considered for a critically dry year. Records of runoff in the Napa River indicate that a firm supply of 5,400 acre-feet would be available under historical runoff conditions during every year except one.

It appears that the Spring Valley Project, if constructed by a local agency for irrigation purposes, could be financed under the "Small Reclamation Projects Act of 1956," Public Law 984, 84th Congress, Chapter 972, 2nd Session. This law provides a method for financing such projects on an interest-free basis.

The estimated capital and annual costs of the Spring Valley Project are presented in Table 24.

TABLE 24

ESTIMATED CAPITAL AND ANNUAL COSTS OF SPRING VALLEY PROJECT

Item	Amount[1]
Capital Cost[1]	
Earth dam embankment	$950,000
Spillway	53,000
Diversion dam	54,000
Pumping plant	147,000
Lands, easements, and rights of way	125,000
Total Capital Cost	$1,329,000
Annual Cost	
Repayment	$26,600
Replacement	2,500
Operation and maintenance	7,900
General expense	3,900
Electrical energy	10,200
Total Annual Cost	$51,100

[1] Based on 1956 construction costs.

The Nicasio Project was authorized by the electorate of the Marin Municipal Water District in November 1956. Construction of the Nicasio Project would create a dam and reservoir near Nicasio in Marin County. The dam would be an earthfill structure with its crest 115 feet above stream bed. The reservoir would provide 23,000 acre-feet of storage capacity. The District estimates that the Nicasio Dam and Reservoir and the main conduit to the District will cost approximately $3,920,000. The firm annual yield of the Nicasio Project was estimated by the Department of Water Resources to be about 12,000 acre-feet.

The North Bay Aqueduct. It has been demonstrated that a need will exist in the North Bay Counties for a system of works capable of supplying about 308,000 acre-feet of water annually by year 2010, in addition to the full use of presently available water supplies. It has also been shown that a very large portion of this water, if available at reasonable prices, would be used for irrigation of presently dry-farmed land. It has further been stated that the plan to be developed for the North Bay Counties will include means of supplying water for the irrigation needs and be financially feasible, but it is not to interfere with existing projects. A single plan which would meet all of these qualifications was not found. However, the North Bay Aqueduct feature of the Biemond Plan was found to conform more closely than its alternatives.

The features of the North Bay Aqueduct necessary to convey water from the Sacramento River to areas requiring imported water in Solano, Napa, Sonoma and Marin Counties are described in Chapter II and shown on Plate 5. This system of works was designed specifically to meet the needs of the water-deficient areas, and because it would deliver untreated water in large quantities, the cost could be held to that which would make it attractive to agricultural, industrial and municipal users. The areas for which the North Bay Aqueduct would provide primary and supplemental service are shown on Plate 9. With the aqueduct in operation, it might be possible to exchange water with the City of Napa, thereby making a portion of the Conn Reservoir water supply available for use in the upper reaches of Napa Valley.

Studies for determination of economic justification were made of the North Bay Aqueduct to compare the annual equivalent costs with the annual equivalent net benefits. The costs included debt service on the capital investment (including nonreimbursable costs), operation and maintenance, power, general expense and a charge for water at the intake. The capital cost of the North Bay Aqueduct was estimated to be $26,760,000, and the annual equivalent cost was estimated to be $1,593,000. (Detailed cost estimates are presented in Appendix A.) The charge for water at the intake was the rate at which water conserved by the Biemond Plan would be sold to assure financial feasibility of that plan. This rate would be about $2.50 per acre-foot and is equivalent to an average annual cost of $384,000 to the North Bay Aqueduct.

Direct benefits would result from the use of the water for municipal and industrial purposes, and for irrigation. The annual equivalent direct benefit from municipal and industrial water was estimated to be $979,000. The annual equivalent direct benefit from agricultural water was estimated to be $1,148,000.

The total direct benefits, $2,127,000, compared to the total direct costs including cost of water at the intake, $1,977,000, results in a benefit-cost ratio of 1.1:1. Therefore, the North Bay Aqueduct was found to be economically justified at the present time.

The financial feasibility of the North Bay Aqueduct was analyzed on the basis of assumed water sales rates,

City of Sonoma—The North Bay Aqueduct could serve this community

California State Chamber of Commerce Phatagraph

Contra Costa Canal—Water from this canol is distributed by the Contra Costo County Water District

U. S. Bureau af Reclamatian Photograph

and an allocation of costs between those features which would be reimbursable and those which would be nonreimbursable. The cost allocation shown in Table 25 would probably apply if the State of California bears the costs of land, easements and rights of way, relocation of utilities, and fish protection facilities. However, such allocations are only assumptions, since the Legislature has not determined policy relating thereto.

TABLE 25

COST ALLOCATION
NORTH BAY AQUEDUCT

Item	Amount[1]
Total estimated capital cost	$26,760,000
Non-reimbursable cost	
Land, easements, rights of way	1,220,000
Relocation of utilities	1,740,000
Fish protection facilities	500,000
Total non-reimbursable cost	$3,460,000
Estimated reimbursable cost	$23,300,000

[1] Based on 1956 construction costs.

The repayment analysis, shown in Table 26, was based upon State construction and financing by general obligation bonds bearing interest at the rate of three per cent. Repayment of the reimbursable cost would be provided by a sinking fund bearing interest at three per cent and would begin in 1971. In addition to the fixed annual operational costs and power, a charge of $2.50 was included for water in the Delta.

An average water rate of about $10.50 per acre-foot would be required to meet the costs during the repayment period; however, farmers could not afford to pay this amount. The repayment analysis was based on rates of $30.00 per acre-foot for municipal and industrial water and $3.50 per acre-foot for agricultural water. Based on these criteria, the aqueduct would require subsidies in the early years of operation when the water sales would be low, but would produce surpluses in the later years when the sales would be greater. The total subsidy required during the repayment period, 1960-2010, would be $17,672,000, and the total surplus would be $21,558,000. Under this type of financing, with the State providing the subsidies and also receiving the surpluses, the North Bay Aqueduct would be financially feasible.

It is pointed out that the economic justification and financial feasibility analyses of the North Bay Aqueduct were based on construction costs prevailing during 1956. It should be recognized that construction costs are increasing and if construction of the North Bay Aqueduct were initiated even during the next two or three years the cost would probably be higher. If the current trend of increasing costs continues, the capital cost of the aqueduct may be about 15 percent greater than the estimated cost based on 1956 construction costs. To assure financial feasibility slightly greater water rates would be required. An agricultural water rate of $3.50 per acre-foot is considered as a reasonable maximum based upon the anticipated crop patterns and, therefore, the urban water rate would have to be increased to between $30.00 and $35.00 per acre-foot. Based upon the method of analysis of direct benefits described herein, the North Bay Aqueduct would be economically justified if its capital cost increases 15 per cent.

Water rights applications No. 17514 and No. 17515 were filed by the State Department of Water Resources with the State Water Rights Board for water to be delivered to the North Bay Counties through the North Bay Aqueduct. Application No. 17514 was for 900 second-feet of water for municipal and industrial use and application No. 17515 was for 900 second-feet for irrigation and domestic use.

Russian River Development

As shown in Table 22, the portion of Sonoma County in the North Coastal Area will not require supplemental water until about the turn of the century, since the Coyote Valley Project will provide 55,000 acre-feet annually in addition to local supplies. The primary service area in which this water will be used is shown on Plate 9. The Sonoma County Flood Control and Water Conservation District is permitted, under terms of its water rights permit, to sell Coyote Valley Project water to agencies in Marin County. However, it is believed that it would not be in the best interest of Sonoma County to distribute this water outside of the Russian River Basin, since the ultimate water requirements of the basin will be almost as great as the developable supply.

The Corps of Engineers has studied a multipurpose flood control and water conservation project on Dry Creek, a tributary to the Russian River. The Coyote Valley Dam is being constructed to permit later enlargement to provide additional flood control and water conservation. The Dry Creek Project, as contemplated by the Corps of Engineers, would yield about 66,000 acre-feet annually, and the ultimate Coyote Project would yield about 135,000 acre-feet annually. It is possible that the requirement for flood control along Dry Creek will result in the construction of the Dry Creek Project prior to the need for supplemental water in Sonoma County.

Studies indicate that the Dry Creek Project would be the next logical development in the Russian River Basin. However, further studies will be necessary to make the final selection among several alternative projects. These studies should be made when it becomes more apparent as to when additional water will be needed.

TABLE 26

REPAYMENT ANALYSIS OF NORTH BAY AQUEDUCT

(Values in thousands)

Reimbursable Cost—$23,300,000
Interest—3 per cent

Year	Annual costs of aqueduct: Interest	Annual costs of aqueduct: Amortization	Annual costs of aqueduct: Fixed operation and maintenance	Annual costs of aqueduct: Power	Cost of water in Delta at $2.50 per acre-foot	Total annual cost	Water sales: Urban: Acre-feet	Water sales: Urban: Revenue @ $30 per acre-foot	Water sales: Agricultural: Acre-feet	Water sales: Agricultural: Revenue @ $3.50 per acre-foot	Water sales: Total: Acre-feet	Water sales: Total: Revenue	Deficiency	Surplus
1961	$699	....	$303	$20	$32	$1,054	5	$150	8	$28	13	$178	$876	....
1962		....		29	58	1,089	6	180	17	60	23	240	849	....
1963		....		39	82	1,123	7	210	26	91	33	301	822	....
1964		....		49	108	1,159	8	240	35	122	43	362	797	....
1965		....		58	132	1,192	9	270	44	154	53	424	768	....
1966		....		68	158	1,228	10	300	53	186	63	486	742	....
1967		....		78	182	1,262	11	330	62	217	73	547	715	....
1968		....		87	208	1,297	12	360	71	248	83	608	689	....
1969		....		97	230	1,329	13	390	79	276	92	666	663	....
1970		....		107	255	1,364	14	420	88	308	102	728	636	....
1971		$309		114	270	1,695	15	450	93	326	108	776	919	....
1972				121	285	1,717	16	480	98	343	114	823	894	....
1973				129	300	1,740	17	510	103	360	120	870	870	....
1974				136	315	1,762	18	540	108	378	126	918	844	....
1975				143	330	1,784	19	570	113	396	132	966	818	....
1976				150	348	1,809	21	630	118	413	139	1,043	766	....
1977				157	368	1,836	23	690	124	434	147	1,124	712	....
1978				164	388	1,863	25	750	130	455	155	1,205	658	....
1979				170	408	1,889	27	810	136	476	163	1,286	603	....
1980				177	428	1,916	29	870	142	497	171	1,367	549	....
1981				182	440	1,933	31	930	145	508	176	1,438	495	....
1982				187	452	1,950	33	990	148	518	181	1,508	442	....
1983				191	465	1,967	35	1,050	151	528	186	1,578	389	....
1984				194	478	1,983	37	1,110	154	539	191	1,649	334	....
1985				198	490	1,999	39	1,170	157	550	196	1,720	279	....
1986				199	502	2,012	41	1,230	160	560	201	1,790	222	....
1987				205	515	2,031	43	1,290	163	570	206	1,860	171	....
1988				208	528	2,047	45	1,350	166	581	211	1,931	116	....
1989				213	542	2,066	48	1,440	169	592	217	2,032	34	....
1990				217	555	2,083	51	1,530	171	598	222	2,128	....	$45
1991				220	568	2,099	54	1,620	173	606	227	2,226	....	127
1992				225	578	2,114	57	1,710	174	609	231	2,319	....	205
1993				228	588	2,127	60	1,800	175	612	235	2,412	....	285
1994				233	598	2,142	63	1,890	176	616	239	2,506	....	364
1995				236	608	2,155	66	1,980	177	620	243	2,600	....	445
1996				241	618	2,170	69	2,070	178	623	247	2,693	....	523
1997				244	628	2,183	72	2,160	179	626	251	2,786	....	603
1998				248	640	2,199	76	2,280	180	630	256	2,910	....	711
1999				251	652	2,214	80	2,400	181	634	261	3,034	....	820
2000				255	665	2,231	84	2,520	182	637	266	3,157	....	926
2001				258	678	2,247	89	2,670	182	637	271	3,307	....	1,060
2002				263	688	2,262	94	2,820	181	634	275	3,454	....	1,192
2003				264	700	2,275	99	2,970	181	634	280	3,604	....	1,329
2004				270	710	2,291	104	3,120	180	630	284	3,750	....	1,459
2005				274	722	2,307	109	3,270	180	630	289	3,900	....	1,593
2006				279	732	2,322	114	3,420	179	626	293	4,046	....	1,724
2007				282	745	2,338	119	3,570	179	626	298	4,196	....	1,858
2008				287	755	2,353	124	3,720	178	623	302	4,343	....	1,990
2009				290	762	2,363	128	3,840	177	620	305	4,460	....	2,097
2010				293	770	2,374	132	3,960	176	616	308	4,576	....	2,202
Totals	....	....	....	....	....	....	....	....	....	....	....	....	17,672	21,558

Solano Project

The Solano Project will have a yield of 262,000 acre-feet annually, including the amount of water required for downstream releases to maintain ground water percolation from Putah Creek comparable to preproject conditions. This project will be able to meet all the requirements of the Solano Irrigation District and be capable of serving land between the District and Reclamation District No. 2068, as shown on Plate 9.

The remaining irrigable land in the portion of Solano County in the Central Valley Area is largely Class 2 and 3 land lying between the Solano Irrigation District and the Delta. It lies at relatively low elevations and could readily be served by direct diversions from the Delta, using surplus water therein, or

water available from either the Central Valley Project or Feather River Project.

South Bay Counties Water Plan

For the most part, the South Bay Counties are in a good position with respect to future water supplies as a result of farsighted planning. The service areas of the San Francisco Water Department, of the East Bay Municipal Utility District, and of the Contra Costa County Water District will have ample water to meet their respective requirements. The areas adjacent to the Delta are in a position to increase their diversions. The local water resources in southern Santa Clara County will be adequate to meet the requirements of that area. The organized water service agencies in the South Bay Counties and the principal sources of supply are shown on Plate 9.

Steps have already been taken to provide supplemental water to most areas in Alameda, southern Contra Costa, northern Santa Clara and San Benito Counties. The State Legislature has authorized, and provided funds for preparation of plans and specifications and purchase of regulatory reservoir sites, for the Alameda-Contra Costa-Santa Clara-San Benito Branch of the Feather River Project Aqueduct. This branch is commonly known as the South Bay Aqueduct.

South Bay Aqueduct. The South Bay Aqueduct would divert water from the Feather River Project Aqueduct about two miles south of the Delta. Water would be pumped into a concrete-lined canal at an elevation of about 700 feet and be conveyed to a tunnel extending through the Coast Ranges into Livermore Valley. It would continue westward around the Valley in a lined canal and pass through tunnels and pipeline into the southern portion of Alameda County near Mission San Jose. It would then follow the eastern side of Santa Clara Valley passing east of Alum Rock, Evergreen and Morgan Hill into the Central Coastal Area. It would continue along the eastern edge of southern Santa Clara Valley to its terminus near San Felipe in the northeastern portion of the Hollister area.

Regulatory storage would be included at Airpoint Reservoir east of Milpitas and Evergreen Reservoir near Evergreen. The alignment of the South Bay Aqueduct is shown on Plate 9.

Since the completion of the original planning on the South Bay Aqueduct, the South Santa Clara Valley Water Conservation District has constructed local water resources projects and will not require supplemental water. The Santa Clara Valley Water Conservation District contemplates further development of percolation areas to increase the yield of its local water conservation works. Also, the local water supplies in the free ground water section of northern Santa Clara Valley, between Evergreen and Morgan Hill, will be adequate to meet water requirements of the overlying area. In view of these circumstances consideration is being given to alternative means of supplying supplemental water to San Benito County. In lieu of the section of the South Bay Aqueduct extending southward from Evergreen, the feasibility of constructing a tunnel through the Coast Ranges at Pacheco Pass is being investigated. The location of this tunnel is also shown on Plate 9. Water would be obtained from the Feather River Project at San Luis Reservoir. These studies have not progressed sufficiently to determine whether this alternative should be recommended in conjunction with a shortened South Bay Aqueduct.

CHAPTER IV

CONTINUING STUDIES

Many of the studies directed by the Abshire-Kelly Salinity Control Barrier Act of 1955 will be continued for sometime into the future. Those studies which are important to the conclusions contained in this bulletin are presented in this chapter.

SUBSURFACE EXPLORATION

The primary purpose of the exploration program is to acquire basic data for the design of project facilities. This program is described under the headings of field operations and laboratory analysis.

Field Operations

In July, 1955, subsurface data, covering the 992 miles of levees in the Sacramento-San Joaquin Delta, were almost nonexistent. Some information was available from the Corps of Engineers, Bureau of Reclamation, California Division of Highways, East Bay Municipal Utility District, and private engineers. However, these data were scanty and for disconnected areas.

A work program was outlined for exploration of foundation conditions along the proposed master levee system alignment. This program was designed to be flexible so that it could be altered, as conditions might dictate. Where information was not available, the program called for drilling at approximately 1,000-foot intervals. The holes would extend through the peat and questionable materials, and far enough into an underlying stratum of firm clay or sand to be assured that the stratum was not a lense underlain by more questionable material. At approximately one-mile intervals, holes would be drilled at least 100 feet deep. All materials encountered at all locations would be carefully logged, and samples would be submitted to the laboratory for analysis. The field operations began in August, 1955, and are continuing. At this date, March, 1957, exploration is nearly complete along the alignment of the proposed master levee system north of the San Joaquin River.

The drilling is being accomplished using two types of equipment: (1) a power-driven, truck-mounted, rotary drill, manned by a crew of four, and (2) a one-inch Porter Soil Sampler manned by a crew of three, and operated with the aid of power supplied from a "jeep." The power drill, operating from a barge, explored foundation conditions at the site of the proposed siphon and control structure near Little Venice Island and at the site of the proposed control structure on Holland Cut. A general summary of the subsurface exploration completed and the depths of peat encountered are presented in Table 27.

Special drilling was conducted near Little Venice Island to obtain foundation data for the design of the siphon under the Stockton Deep Water Channel, the control structure on Little Venice Island, and the channel closures in connection with the Cross-Delta Canal. A total of 16 holes, varying from 100 feet to 150 feet in depth, were drilled by means of equipment operating from a barge. The material encountered was predominantly fine to medium-grained sand, with relatively thin lenses of stiff clays. These materials would not cause any unusual foundation problems in the design of the structures.

The repair of a partial levee failure on Twitchell Island provided an opportunity to acquire basic information on the behavior of peat and organic silts under field conditions. Instruments were installed, in and adjacent to the levee, prior to its reconstruction, to provide a means of observing vertical and horizontal movement of subsurface materials, and changes in pressures. Periodic observations were taken prior to and during the construction, and are being continued.

TABLE 27

SUMMARY OF SUBSURFACE EXPLORATION PROGRAM

Island	Length of levee explored, in miles	Number of holes	Thickness of organic material, in feet		Average elevation of basement sand, in feet below mean sea level datum
			Range	Average	
Andrus	2.7	21	5–45	35	45
Brack	2.5	12	10–22	15	15
Bouldin	3.8	21	10–40	25	30
Canal Ranch	2.7	9	5–15	12	15
Empire	5.7	25	10–25	20	25
McCormack-Williamson	2.3	9	2.5	2	5
Medford	5.5	29	15–30	20	30
New Hope	3.0	12	1–4[1]	--	5
Rindge	6.8	20	15–30	20	25
Sherman	18.9	91	10–80	40	50
Staten	13.3	65	10–18	14	30
Terminous	5.3	26	5–30	20	25
Twitchell	6.1	32	12–37	25	35
Venice	7.6	39	15–30	20	30

[1] Isolated lenses.

The tentative conclusion, based upon the explorations conducted to date, is that the portion of the Delta lying to the north of the Stockton Deep Water Channel is underlain by a nearly continuous blanket of sand at depths varying generally from 15 to 50

feet below mean sea level. The foundation problems, associated with levees in the Delta, relate to the organic deposits overlying this sand base. It is possible that the existence of this continuous sand base has a bearing on seepage problems, or wet spots, on some of the islands.

Laboratory Analyses

Primary and secondary soil tests were conducted in the Department of Water Resources soils laboratory on samples acquired during the field operations in the Delta area.

Primary laboratory testing was principally to classify material and to determine soil bearing strengths. Samples were tested to determine composition, dry and wet densities, percentage of organic material, moisture content, and unconfined compressive strength. Samples containing a large proportion of silt and sand were subjected to mechanical analysis, specific gravity, and Atterburg limits tests.

Secondary testing involves more intensive testing of fewer samples than the primary tests on a large mass of samples. Consolidation, triaxial compression and permeability tests are the principal secondary tests. Data obtained from the secondary testing are used to develop criteria for use in levee and foundation design. The results obtained from the secondary program provide a standard to be compared and correlated with results obtained by the primary testing.

WATER QUALITY

Studies have been conducted, and are being continued, in three separate fields of water quality. These studies relate to (1) flows required to maintain the line of 1,000 parts of chlorides per 1,000,000 parts of water 0.6 mile below Antioch, (2) ground water underlying the Delta, and (3) water quality problems of the San Joaquin Valley.

Salinity Control Flows

The quantity of fresh water required to maintain the mean tidal cycle line of 1,000 parts of chlorides at a point near Antioch, under conditions which would exist with the Biemond Plan in operation, was estimated using two separate methods. The first method was developed during studies conducted by the Division of Water Resources, Department of Public Works, and published in 1931 as Bulletin No. 27, "Variation and Control of Salinity." The second method used was developed during the present investigation of salinity control barriers.

The method presented in Bulletin No. 27 develops a relationship between streamflow, tidal diffusion, and advances of salinity. This relationship is expressed as net streamflow equals tidal diffusion. Tidal diffusion is defined as the effect of tidal action on the total advance of salinity during a given time interval. Utilizing data presented in Bulletin No. 27, it was possible to construct a graphical relationship between tidal diffusion and tidal prism volume, the quantity of water which flows past a given point due to tidal action. From this graphical relationship, it was possible to determine the tidal diffusion for the tidal prism volume which would result from construction of the Biemond Plan. As the tidal diffusion is expressed as net streamflow, the quantity of fresh water required to control salinity could be estimated. The computed Delta tidal prism volume with the Biemond Plan in operation was based on the assumption that Franks Tract and Big Break would remain inundated, and that the Sacramento Deep Water Channel would be completed. It was further assumed that construction of the Biemond Plan would not alter the present tidal amplitude, and that the accretions within the Delta (500 second-feet), would remain constant. This method indicated that a flow of about 1,150 second-feet into Suisun Bay would maintain the line of 1,000 parts of chlorides near Antioch with the Biemond Plan in operation.

The second method used to determine the required outflow under the Biemond Plan established the relation between the tidal prism volume above the line of 1,000 parts of chlorides and the outflow to Suisun Bay. Sufficient data were available to establish a curve through a range of tidal prism volumes and flows. By entering this curve with the computed mean tidal prism of the Biemond Plan above Antioch, it was possible to obtain an estimate of the required outflow. This method indicated that about 1,250 second-feet would maintain the line of 1,000 parts of chlorides at the desired location with the Biemond Plan in operation.

The two methods gave results of 1,150 second-feet and 1,250 second-feet, a difference of less than 10 per cent. For study purposes, the average of the two, or 1,200 second-feet, was used as the required outflow to Suisun Bay.

It is pointed out that both methods used in these analyses assume that the Biemond Plan would not change the tidal amplitude. The electronic analog, being constructed by the University of California will disclose the validity of this assumption. When data become available from the analog, reanalysis of the required outflows from the Delta may be necessary.

Ground Water in Sacramento-San Joaquin Delta

Concurrent with the subsurface exploration program to determine foundation conditions, observations were made to determine the depth, location and quality of saline water known to underlie portions of the Delta. To date, observations have been limited to areas lying generally north of the Stockton Deep

Water Channel. While this program has been of limited scope, the data obtained are extremely valuable and warrant mention.

Ground waters in the areas surrounding the Delta are generally of excellent quality with low dissolved mineral content. These waters vary from a calcium-magnesium-bicarbonate water to a sodium-bicarbonate water with moderately low total dissolved solids.

A relatively large area in the central portion of the Delta is underlain by poor quality ground water at relatively shallow depths. This water is a saline water entrapped during geological formation (hereinafter referred to as connate water), which generally contains high percentages of sodium and chloride and relatively low concentrations of calcium sulphate. This area is known to encompass the eastern portions of Twitchell and Brannan Islands, the southern portion of Staten and Andrus Islands, and practically all of Bouldin Island. The western portion of Terminous Tract and the central part of Rindge Tract, along with other areas not positively defined are included. The chloride content of water samples taken from under these islands was found to vary from 120 ppm to a high of 2,200 ppm. It is from this central area that rising waters of poor quality gain access to surface waters.

Water Quality in the San Joaquin Valley

Mineral quality of surface waters in San Joaquin Valley is extremely variable. East-side streams, comprising runoff from the granitic Sierra Nevada, are of high quality before their emergence on the valley floor. The quality of the water deteriorates thereafter, due to degradation by sewage and industrial waste waters, and drainage from irrigated lands which conveys dissolved minerals leached from agricultural chemicals and the soil itself.

West-side streams flow only during, and for a short time after the infrequent winter rains. Their runoff originates in watersheds composed largely of marine sediments, saturated in past ages with sea salts. These salts, redissolved and transported toward the valley floor, account for the high salinities observed in such streams as Panoche, Little Panoche, Silver and Los Gatos Creeks.

Oil field brine discharges are also a factor in the high salinity of such streams as Sandy Creek, Buena Vista Creek, and Broad Creek in Kern County. In many cases, water in west-side creeks is unfit for irrigation of salt-sensitive crops, but can be used successfully with such salt-tolerant crops as cotton, sugar beets and pasture grasses.

Ground waters as a rule reflect the mineral quality of the surface waters which recharge them. Accordingly, wells in the east side of the valley produce water of good quality, while those on the west side are poorer and often suitable only for the most hardy crops. West-side ground waters are more saline, not only because inferior surface waters from local streams contribute to the ground water basin, but also because of high water table conditions resulting from poor drainage. When the water table stands at or near the ground surface, water is evaporated, but the dissolved salts are crystallized out of solution and are left behind. Salt content of the remaining water is thereby concentrated.

A further source of mineral degradation of well waters is found in the connate brines which occur in many parts of the valley at depths of 400 feet or more. These are believed to have moved upward from the deep-seated marine sediments which underlie the valley alluvium, sometimes at depths of many thousands of feet. Extraction of overlying fresh waters tends to accelerate the rise of this saline water.

The foregoing factors have caused the average quality of water of the San Joaquin River to deteriorate at all points below Mendota by 30 per cent or more since 1951. The quality of the water between Mendota and Mossdale Bridge is now approaching the limit of tolerance for certain salt-sensitive crops. Studies made by the Water Quality Branch of the Department of Water Resources indicate that water quality problems of the San Joaquin Valley will worsen in the future unless provisions are made to collect, convey and dispose of the unusable waste waters.

Based upon studies of water quality in the San Joaquin Valley, as prepared for The California Water Plan, it was estimated that it would be necessary, under ultimate conditions of development, to provide for the drainage and exportation from the valley of about 1,100,000 acre-feet of water per season. Provisions were included in The California Water Plan to accomplish this objective. The works, designated as the San Joaquin Waste Conduit, would originate near Buena Vista Lake in Kern County, and terminate in the Delta. It is emphasized that the San Joaquin Waste Conduit, as presented in The California Water Plan, was a possible solution based solely upon very preliminary-type office studies. An intensive investigation of the San Joaquin Valley drainage problems has been recommended by the Department of Water Resources.

It is pointed out that even under the Biemond Plan, the disposal of low quality drainage water from the San Joaquin Valley into the San Joaquin River would pose a problem to the Delta landowners. Many crops in the Delta receive a portion of their water supply through sub-irrigation. This water enters sand strata which underlie the islands and the San Joaquin River. Thus, quality degradation of water in the river would be a threat to the agriculture.

Solutions to this problem are still under study. However, two possible corrective measures are readily apparent. The first of these would be to carry the low

quality San Joaquin River drainage water in an isolated system and dispose of it at some downstream point. One possible alignment for this system is shown on Plate 3. This alignment has not been field checked, nor studied to determine its cost. The alignment would, however, coincide with the location of a disposal conduit being planned by Contra Costa County. The introduction of large quantities of highly mineralized water into the San Joaquin River near the Antioch Bridge, would probably require a policy change regarding the location of the line of 1,000 parts of chlorides. The second alternative would be to dilute the low grade water with releases of high quality water from the Cross-Delta Canal. It is conceivable that during the early years of operation of The California Water Plan, the latter solution could be used, and when water became more costly, the drainage canal constructed.

Solutions to the water quality problems of the San Joaquin Valley are not within the scope of the Salinity Control Barrier Investigation. However, when solutions to those problems are being developed, consideration must be given to the rights of property owners in the Delta.

HYDROLOGY

During the course of the investigation that led to the March, 1955, report, a contract was executed with Dr. H. A. Einstein of the University of California to investigate the effects of barriers on the regimen of the tides. Dr. Einstein's investigation was limited to a study of the effect of barriers at Dillon Point and Point San Pablo. At the start of the current investigation, it was concluded that further examination of the effects of the Chipps Island Barrier Plan and the Biemond Plan would be required.

A committee, composed of representatives of the Bureau of Reclamation, Corps of Engineers, University of California, and the Department of Water Resources was formed to consider the problem. It was concluded that an electronic analog would produce the desired results within the shortest time, and at the lowest cost. An electronic analog would simulate hydraulic characteristics of tidal channels with electrical components.

A contract was awarded to the University of California for the construction of an electronic analog on April 1, 1956. It was stipulated that the University would construct and operate the analog to include analysis of the following problems:

1. Distribution of fresh water flow (both summer and flood flows) in the Sacramento-San Joaquin Delta under (1) present conditions, (2) conditions with a Sacramento Deep Water Channel, and (3) conditions with Feather River Project in operation without a barrier.
2. Tidal amplitudes after construction of the Biemond Plan.
3. Recommended sequence of closure of channels during construction of plan.

To date, preliminary results from the analog indicate that a substantial increase in tidal amplitude would be experienced in Suisun Bay with a barrier at Chipps Island while the construction of the Biemond Plan would have very little effect on the tidal amplitude in the Delta. Studies with the electronic analog will be completed by June 30, 1957.

FISH AND WILDLIFE

Throughout this investigation, funds have been made available to the State Department of Fish and Game, through inter-agency service agreements, for studies of the fish and wildlife aspects of salinity control plans. Further studies leading to the evaluation of the effect of the Biemond Plan on fisheries and wildlife, and the development of detailed plans to protect these important resources, will be undertaken during the remaining years of the investigation. The major fish and wildlife problems are those concerned with passing upstream migrant fish around the control structures, and preventing the loss of young downstream migrants at diversions. The principal species of fish involved are striped bass, salmon, steelhead, shad, and sturgeon. All of these species support important recreational fisheries, and the salmon and shad are also taken commercially.

A vertical baffle fishway (sometimes called a Hell's Gate-type fishway) was recommended by the California Department of Fish and Game as a possible means of passing the fish around the control structures. The vertical baffle fishway consists of a series of interconnected bays. The slots connecting these bays extend from the water surface to the floor and it is, therefore, unnecessary for the fish to leap from pool to pool, as they do in the conventional fish ladder. It is only necessary for them to swim through a short distance of swift water and then rest in the next bay. This type of fishway has been in operation for several years in Washington and Canada, and has proven to be highly successful when used for salmon and steelhead. However, it has not been tested with striped bass or shad, two of the principal species found in the Delta and river system. For this reason, a vertical baffle fishway, containing two bays, was constructed on the Grizzly Island Waterfowl Management Area and is being tested by the Departments of Water Resources and Fish and Game.

Tests have already been made of the velocities through the slots and head-losses and turbulence in the bays. Tests with fish are scheduled to be conducted during the early part of 1957. It is believed that this activity will provide much needed data to both the

biologists and the engineers, with the final result that better fishing will be available to the sportsman.

Another important consideration will be the effect of the Biemond Plan on waterfowl wintering in the Suisun marshlands. Possibilities exists for an over-all enhancement of these waterfowl resources, due to the increases in food production made possible by fresh water from the North Bay Aqueduct.

STAGING OF THE BIEMOND PLAN

The Biemond Plan, lends itself to a variety of possible construction stages. For example, early construction of the Feather River Project Pumping Plant would require improvement of Holland Cut, and Old River between Franks Tract and Italian Slough. This construction should include provisions to make it readily amenable to later inclusion with the Biemond Plan. The channel improvement of the South Fork of the Mokelumne River, as called for under the Biemond Plan, even without severing connecting sloughs, would provide flood control benefits to both Delta and upstream landowners. Construction of this improvement would be highly desirable in the immediate future.

As demonstrated by the floods of December, 1955, nearly every Delta island requires additional work on its levees. The continuing studies will develop a recommended time-table for the construction of all elements of the Biemond Plan. The electronic analog will provide valuable information in determining the proper sequence of closing the Delta channels. Undoubtedly, many of these channels would remain open for many years, while others might be advantageously closed when the Feather River Project Pumping Plant is placed in operation.

The staging of construction of the Biemond Plan will play an important role in the financial feasibility of the plan. These studies must be thorough and complete.

WATER RIGHTS

It was stated in Chapter II that studies leading to this bulletin were based upon the assumption that salinity would be controlled so as to maintain usable water at points inland from a line approximately 0.6 mile west of Antioch. It was also indicated that an outflow of approximately 3,800 second-feet was assumed, for purposes of this bulletin, to be required for salinity control. Further study is necessary to verify the amounts of fresh water needed to accomplish this objective under existing conditions. The determination of the party or parties responsible for providing salinity control will also be important, as this responsibility will be a basic consideration in the financial feasibility studies of the Biemond Plan. These matters are elements of the total picture of water rights along the Sacramento River and in the Sacramento-San Joaquin Delta, which will be the subject of negotiations planned for the near future between the United States Bureau of Reclamation and the water users.

These pending negotiations are the outgrowth of a period of controversy over relative water rights which began in 1920. The Antioch suit, filed in that year by the City of Antioch against upstream water diverters, was the first manifestation of the differences between the interests of those in the Delta area and of the diverters upstream from Sacramento. While the construction of the Central Valley Project by the United States Bureau of Reclamation alleviated the water shortages by making available stored water in dry years, this complicated the water rights problems. The differences among the local water users, and between those water users and the United States Bureau of Reclamation threatened at one point to result in widespread litigation. As a consequence, a joint legislative committee comprising representatives from the United States House of Representatives and the California Legislature met in 1951 in an attempt to pinpoint the problems and to recommend a solution. This led to a series of conferences, called by the Governor, which resulted in an agreement among the United States Bureau of Reclamation, the water users, and the State to attempt to solve these problems by compromise, so as to avoid complicated and costly law suits. This agreement resulted in the so-called Trial Distribution Programs in the 1954 and 1955 irrigation seasons, which were designed to collect additional data on diversions, stream flows, and other matters, and to analyse these data in order to present necessary information to the parties of the program, including conclusions as to the effectiveness of certain scheduled inflows to the Delta for salinity control purposes.

In 1956, a Cooperative Study Program was undertaken by representatives of the three interested groups, and a report on the findings is in process of publication at this time. That report will indicate the degree of satisfaction of various water rights under different assumptions, and the amounts of water that are required to supplement natural water supplies in order to provide firm water supplies and to provide effective salinity control. It is anticipated that this information, together with information being compiled currently by other interested parties, will permit early commencement of actual negotiation of an agreement covering water rights, including those in the Delta, and provision of salinity control.

It is anticipated that the first consideration with respect to salinity control will be an attempt to resolve the matter as to the actual extent of salinity control to be provided in the Delta area. The other question to be resolved is the financial responsibility for this salinity control as it may be distributed among the local water users and the governmental agencies. These are questions which are presently

unresolved, and must of necessity await the results of the anticipated negotiations for definition. Obviously, no final conclusion may be drawn as to the financial aspects of the Biemond Plan until these questions are settled.

FINANCIAL RESPONSIBILITY

Prior to construction of the Biemond Plan, intensive studies would be necessary to determine the respective financial responsibilities of the Federal, State and local interests. While the existence of this problem is recognized, little progress in its resolution has been accomplished to date.

The Biemond Plan would provide a high degree of flood protection to lands situated in the Delta. Only a cursory examination of the flood control benefits of the plan has so far been made. Requests have been made to the President and the Congress for a Federal evaluation of these flood control benefits, and it is believed that Federal participation at the investigational level can be expected in the near future. Allocation of costs related to the flood control benefits of the Biemond Plan is complicated, as the facilities which would provide the necessary protection would also result in conservation of water. The levees located along the Cross-Delta Canal would provide flood protection, while aiding in the transfer of water. While these complications exist, real and very large flood control benefits would be realized from construction of the Biemond Plan. These benefits must be evaluated and a proper allocation made to flood control.

Just as the flood control and water conservation aspects of the plan are intermixed, so are the cross-Delta water transfer aspects. The Cross-Delta Canal of the Biemond Plan was designed to transfer water developed by the plan, and waters of both the Central Valley and Feather River Projects. As it is probable that the cross-Delta movement of water under these projects would be benefited by Biemond Plan facilities, an equitable allocation of costs must be made.

It is anticipated that State policy will be forthcoming regarding nonreimbursable costs of State-constructed water projects. In the case of the Biemond Plan for purposes of this report, it was assumed that the costs of the following items would be nonreimbursable and, therefore, would be borne by the State: land, easements and rights of way; fish protection facilities; relocation of roads, railroads and bridges; and locks.

Construction of the Biemond Plan would greatly improve accessibility to many of the Delta islands, thereby relieving the counties of the financial burden of maintaining ferries at numerous locations. The counties might find it to their advantage to contribute to and promote construction of certain channel closures to gain this transportation benefit.

DELTA IRRIGATION AND DRAINAGE

Since the very earliest reclamation of the Delta islands, water for surface irrigation has been taken from the adjacent channels. Excess irrigation water along with seepage, precipitation, and water applied for leaching purposes, has been returned to the same channels. Under operation of the Biemond Plan, some of the islands could siphon water directly from the isolated Cross-Delta Canal and dispose of their waste waters into tidal channels. However, the majority of the islands would continue to acquire their irrigation water from the same channels and in the same manner as they do today. Many of these channels would no longer be under tidal influence, nor would they be degraded by return flows of the San Joaquin Valley, or invading saline water of the Bay system. High quality water would be released to the isolated interior channels from the Cross-Delta Canal and sufficient water would be removed therefrom to maintain necessary quality.

A preliminary study of an irrigation and drainage plan to operate in conjunction with the Biemond Plan has been completed. This study disclosed that the quality of water applied in the Delta would be equal to or better than that which is presently used for irrigation. It was further shown that in the southern portions of the Delta, the water would be of greatly improved quality, as, under the controlled condition, the poorer quality water would always flow toward a point of disposal. The irrigation and drainage features of the plan would be carried as project costs.

The continuing studies of irrigation and drainage in the Delta will include interviews with the landowners. The information obtained from these interviews will be incorporated into the final layout and design of diversion and return facilities.

It is emphasized that the Biemond Plan would in no way adversely affect the water rights of the Delta landowners.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The investigation of salinity control barriers, authorized by the Abshire-Kelly Salinity Control Barrier Act of 1955, is now (March, 1957) approximately 30 per cent complete. During the 21-month period which has elapsed since the study was initiated, valuable basic data have been gathered and important conclusions have been reached.

SUMMARY

The ever-increasing need for water in the water-deficient portions of California demands that large quantities of water be conveyed from the Sacramento River Basin and the North Coastal Area, to the San Joaquin Valley, San Francisco Bay Area, and southern portions of California, without undue loss of water to Suisun Bay, and without degradation of quality or damage to existing operations during the transfer. The channels of the Sacramento-San Joaquin Delta, presently used by the Central Valley Project in the transfer of water from north to south, will continue to be used under operation of the Feather River Project in its early years. While the water from the Sacramento River can find its way to the existing and proposed pumping plants through interconnecting sloughs and channels, it can also flow uncontrolled into San Francisco Bay.

The Sacramento-San Joaquin Delta, through which this fresh water must be transferred, contains nearly 500 miles of interconnected tidal sloughs which isolate some 50 tracts or islands. These islands are composed of organic soils which make them highly productive, but extremely difficult to protect from inundation. Due to wind erosion, compaction and oxidation of the organic soils, the surface of most of the islands now lies at elevations below sea level. Efforts by the landowners to raise the heights of the protecting levees are hampered by poor foundation conditions. If this valuable agricultural area is to be maintained, a dependable system of levees must be constructed.

Recognizing the importance of the Sacramento-San Joaquin Delta as related to California's water and land resources, the State Legislature in 1953 directed that an investigation be conducted to determine the feasibility of alternative plans to provide the needed control of floods, and to provide regulation of the fresh water flow to Suisun Bay and intrusion of saline water into the Delta channels. That investigation resulted in the recommendation that further consideration of salinity control barriers be restricted to the Junction Point Barrier Plan and Chipps Island Barrier Plan. In 1955, the Legislature directed that these two plans be studied in greater detail.

The Junction Point Barrier Plan, shown on Plate 2, was originally designed in accordance with suggestions made by Cornelus Biemond of The Netherlands. This plan would provide control over both flood and fresh water flows by restricting them to designated channels. The Junction Point Barrier Plan called for control structures across Sacramento River and Steamboat Slough, an isolated channel to convey fresh water across the Delta, a Delta flood control plan, and aqueducts to deliver the conserved water into the San Francisco Bay Area. During the current investigation, the Junction Point Barrier Plan was reviewed, modified as found desirable, and renamed the "Biemond Plan."

The Biemond Plan, shown on Plates 3 and 4, would provide greater control over the fresh water entering the Delta than would the original Junction Point Barrier Plan. It would also be less costly, as certain channels would serve both in the transfer of fresh water across the Delta and in the conveyance of flood flows through the Delta. As with the Junction Point Barrier Plan, groups of islands would be enclosed within a master levee which would reduce the total length requiring maintenance against floods from about 1,000 miles to about 450 miles. Locks would be provided at the control structures on the Sacramento River and on Holland Cut.

The North Bay Aqueduct, a feature of the Biemond Plan and shown on Plate 5, would be capable of delivering untreated water to potential service areas in the Fairfield-Suisun marshlands, in Napa, Sonoma, and Petaluma Valleys, and in portions of Marin County. The aqueduct, with an over-all length of 59 miles, would have a capacity of 900 second-feet at its point of diversion from Lindsay Slough in the Delta, and would terminate in a small reservoir near Novato in Marin County. The aqueduct, between these points, would include reaches of unlined and concrete-lined canal, pipeline and tunnel.

The Biemond Plan was found to be physically feasible of construction. It could be successfully operated to transfer large quantities of water across the Delta without undue loss to Suisun Bay or degradation of quality during the transfer. The Biemond Plan would also provide a high degree of flood protection to Delta lands. The plan would be capable of conserving about 937,000 acre-feet of water annually from supplies

which would be required under present conditions to maintain the line of 1,000 parts of chlorides per million parts of water near Antioch, without changing the location of this point of salinity control.

The Chipps Island Barrier Plan, shown on Plates 6 and 7, would control the outflow to Suisun Bay by placing structures between the fresh water of the rivers and the salt water of the bays. All inflows to the resultant fresh water pool, including return flows from the San Joaquin River, would commingle in the Delta. Flood protection would be provided by a system of master levees. Locks would be provided at the barrier structure to permit passage of ships.

The Chipps Island Barrier Plan was reviewed and modified during the current investigation. The main alterations were to provide a master levee system similar to that included with the Biemond Plan and to change the type of locks from conventional to salt-clearing. The Modified Chipps Island Barrier Plan is shown on Plates 6 and 8. The modified plan was found feasible of construction, and could be operated to provide good quality water throughout the Delta, as well as providing flood protection therein.

Under operation of the Chipps Island Barrier Plan, secondary treatment would be required for nearly all sewage entering the proposed barrier pool, and, furthermore, interception and disposal of the most highly mineralized industrial wastes would be required. Preliminary findings, obtained by means of an electronic analog, indicate that a barrier at Chipps Island would greatly increase the tidal amplitude downstream from the principal structures. The plan would conserve about 1,675,000 acre-feet of water annually from supplies presently used to repel salinity.

The relative merits of the Biemond Plan, and of the Modified Chipps Island Barrier Plan, can be seen by inspection of Table 28. All elements of the two plans were analyzed under the same basic criteria. For this comparison, it was assumed that all units of the two plans would be constructed simultaneously. This assumption provides an apparent economic advantage to the Chipps Island Barrier Plan, as it is less adaptable to staging of construction than is the Biemond Plan.

TABLE 28

COMPARISON OF BIEMOND PLAN WITH MODIFIED CHIPPS ISLAND BARRIER PLAN

Item	Biemond Plan	Chipps Island Barrier Plan
Capital cost[1]	$86,200,000	$198,900,000
Annual equivalent cost	$4,789,000	$10,966,000
Annual equivalent benefit	$10,850,000	$16,173,000
Benefit-cost ratio	2.3:1	1.5:1
Water conserved	937,000 a.f.	1,675,000 a.f.
Operational losses	876,000 a.f.	352,000 a.f.
Detriments		
Commercial navigation	Minor	Major
Fish and wildlife	Minor	Major
Existing industries	Negligible	Minor

[1] Based on 1956 construction costs.

Studies were made to determine the works needed to deliver sufficient water to the San Francisco Bay Counties to meet their demands during the period, 1960-2010. These studies disclosed that the population of the area would nearly triple during the period, and that the irrigated acreage would remain about constant. It was found that works, in addition to those which exist at the present time, or are in the advanced planning stage, will be needed in the Russian River Basin by the year 2000, and that works capable of ultimately delivering over 300,000 acre-feet of water annually to the portions of the North Bay Counties draining to the San Francisco Bay system are needed now. Nearly all additional population, as well as any increase in irrigated acreage in Petaluma and Sonoma Valleys, must be accompanied by development of additional water supplies.

Those elements of The California Water Plan designed to serve water to Marin, Sonoma, Napa, and Solano Counties were reviewed to select projects which would be capable of meeting the needs of these counties during the 50-year period beginning in 1960. Projects proposed for construction on the Eel River were found to be too expensive for construction to meet the needs of the North Bay Area alone, and insufficient data exist to predict the date at which other water demands of California would justify their construction. Due to these uncertainties, the Eel River projects were dropped from further consideration at this time, since water must be supplied to portions of Sonoma and Marin Counties in the very near future. Water of the Putah Creek Basin is presently being developed by construction of the Solano Project. With the completion of that project, the exportable water supply of Putah Creek will be put to use within the boundaries of Solano County. Therefore, the Putah Creek Basin cannot be considered as a source of water for Napa, Sonoma, and Marin Counties.

The initial stage of the Coyote Valley Project, now under construction by the United States Corps of Engineers on the East Branch of the Russian River, will be capable of meeting the water needs in the Russian River Basin until about the turn of the century. Water from this project could also be exported from the basin and used in Petaluma and Sonoma Valleys, and in Marin County. Were these areas to acquire water from that source, projects such as those proposed by the United States Corps of Engineers on Dry Creek, or the second stage of the Coyote Valley Project, would be required in the Russian River Basin to sustain the export demands. While such a system of works would be physically feasible, it would not supply water at prices which would permit its use for irrigation in the lower Petaluma and Sonoma Valleys.

The local projects which might be constructed within the San Francisco Bay drainage portion of the North Bay Counties would develop only relatively small quantities of water. Two of these projects, the Nicasio Project in Marin County and the Spring Valley Project near St. Helena in Napa County, should be considered for construction by local agencies.

The North Bay Aqueduct proposed herein would be capable of delivering sufficient quantities of untreated water from the Sacramento-San Joaquin Delta to meet the supplemental water demands of the Fairfield-Suisun marshlands, Napa Valley, Sonoma and Petaluma Valleys, and portions of Marin County during the period, 1960-2010. This unit of the Biemond Plan could obtain its water from supplies available in the Delta, supplemented by water purchased on an interim basis from the Central Valley Project or Feather River Project, until the remaining features of the Biemond Plan are constructed. Such a coordinated plan of operation would lend financial support to the Central Valley Project, or Feather River Project, while their service areas are being developed. Upon completion of the remaining features of the Biemond Plan, a portion of its yield would be specifically assigned to the aqueduct.

Studies were made to determine the economic justification and the financial feasibility of the North Bay Aqueduct. These studies indicated that the total direct net benefits, when compared to the total direct costs, including the cost of water purchased at the point of diversion from Lindsay Slough, resulted in a benefit-cost ratio of 1.1:1. Secondary benefits were not appraised. Lacking a legislative policy relating to reimbursable and nonreimbursable costs on projects in which the State may participate, it was assumed that the cost of lands, easements and rights of way, relocation of utilities, and fish protection facilities would be nonreimbursable. Based upon this assumption, and further assuming that the cost of the aqueduct would be amortized at the rate of three per cent interest, the aqueduct would be financially feasible, if the water were sold at an average rate of about $10.50 per acre-foot. This average rate would be realized if water were sold at $3.50 per acre-foot for irrigation purposes, and $30 per acre-foot for municipal and industrial uses which is within the repayment capability of the water users. Revenue, in addition to that received from sale of water, would be required during the first years of operation. However, the revenue from the sale of water during the 50-year period of repayment would be sufficient to recover all reimbursable and operation and maintenance costs, including the subsidies from other sources during the initial years of operation.

It is emphasized that the foregoing financial analyses were based upon construction prices which prevailed during 1956. If construction of the North Bay Aqueduct is delayed three years, its cost might increase by as much as 15 per cent due to rising construction costs alone. It is further indicated, that due to rapid urbanization of areas through which the aqueduct must pass, any delay in acquiring land, easements and rights of way, may well result in much greater costs for these items than is estimated herein.

In the Counties of Contra Costa, Alameda, Santa Clara, San Benito, San Mateo, and San Francisco, the demands for water during the period, 1960-2010, can be met by enlargement of existing systems, or systems such as the South Bay Aqueduct, which have been authorized for construction. The City of San Francisco has plans for expanding its Hetch Hetchy system to a capacity of at least 448,000 acre-feet annually; the East Bay Municipal Utility District is actively promoting development of the Mokelumne River to import up to 364,000 acre-feet of water per year from that source; and, it is estimated that the Contra Costa Canal is capable of importing about 146,000 acre-feet annually. The South Bay Aqueduct has been authorized for construction by the State with a capacity of 240,000 acre-feet of water per year. In addition to these import systems, the South Bay Counties have about 334,000 acre-feet of water available from local storage projects and underground basins, not including the rights of those areas immediately adjacent to the Delta. The aforementioned import projects, if operated conjunctively with the local conservation projects and water supplies in the Delta, will be capable of delivering sufficient water to meet the needs of the South Bay Counties even beyond the year 2010.

CONCLUSIONS

The studies conducted between July, 1955, and March, 1957, resulted in the following conclusions:

1. The Biemond Plan is functionally and economically superior to the Chipps Island Barrier Plan. In view of this conclusion, and recognizing the large difference between the ratio of direct net benefits to costs of the Biemond and Chipps Island Barrier Plans (2.3:1 and 1.5:1, respectively), it is concluded that further consideration should be given only to the Biemond Plan.

2. The North Bay Aqueduct is economically justified and financially feasible, under the assumed criteria set forth in this bulletin. It is superior to other means of serving supplemental water to the North Bay Counties, and was the only plan found to be capable of delivering large quantities of water to the San Francisco Bay drainage portions of the North Bay Counties at prices which would permit its use for irrigation purposes. However, because of subsidies which this project would require during the first years of operation, it would probably have to be constructed by either a multicounty district, the State of California, or an agency of the United States Government.

3. The Coyote Valley Project, on the East Branch of the Russian River, operated conjunctively with existing water supplies, could meet the water needs of the Russian River Basin until about the year 2000. When the Coyote Valley Project is no longer capable of meeting the water demands of the Russian River service area, the Dry Creek Project, and the second stage of the Coyote Valley Project, should be given thorough study, if not yet constructed for flood control purposes, to determine the most feasible plan.

4. The portion of Solano County within the Solano Irrigation District can be supplied with sufficient water to meet its supplemental demands during the period 1960-2010 from the Solano Project and ground water basins. The area in Solano County lying east of the District can be served by water taken from the Sacramento River and by use of ground water supplies.

5. The water demands of the Counties of Alameda, Contra Costa, San Benito, San Francisco, San Mateo, and Santa Clara, can be met by water supplied from the Delta and local developments, supplemented by existing and authorized import systems. The import systems would include the Contra Costa Canal, the Mokelumne River development as planned by the East Bay Municipal Utility District, the Hetch Hetchy system as planned by the City of San Francisco, and the State-authorized South Bay Aqueduct.

RECOMMENDATIONS

As the result of the investigation leading to this bulletin, it is recommended that:

1. Future studies of salinity control barriers be limited to the Biemond Plan, and that the studies now in progress relating to the plan, be carried to completion.

2. The North Bay Aqueduct, as described in this bulletin, be authorized for construction as a feature of The California Water Plan, since, under the assumed criteria, it is economically justified and financially feasible, and the North Bay Counties are urgently in need of a supplemental water supply.

3. Funds be appropriated for the following purposes in connection with the North Bay Aqueduct:

a. Acquisition of land, easements, and rights of way	$1,220,000
b. Preparation of construction plans and specifications	1,340,000
Total	$2,560,000

4. Expenditure of funds for preparation of construction plans and specifications of the North Bay Aqueduct be made contingent upon reasonable assurance from the prospective water users of their willingness to assume the obligation for repayment of the reimbursable costs.

5. A policy relating to reimbursable and nonreimbursable costs be established by the Legislature.

APPENDIX

ESTIMATED CAPITAL AND ANNUAL COSTS—NORTH BAY AQUEDUCT

Item	Unit	Quantity	Unit cost	Item cost	Amount
CAPITAL COST					
Lindsay Slough to Calhoun Cut Pumping Plant (Mile 0 to Mile 3.79, 900 c.f.s.)					
Excavation	cy	250,000	$0.30	$75,000	
Trimming	lf	20,000	2.00	40,000	
Bridge, county road	sf	3,000	12.00	36,000	
Traffic control	LS			9,000	
Subtotal, Field Cost					$160,000
Calhoun Cut Pumping Plant (Mile 3.79, 900 c.f.s.)					
Structure	LS			$186,000	
Pumps, 225 c.f.s. (one standby unit)	ea	5	$24,000	120,000	
Motors, 450 horsepower	ea	5	14,700	73,500	
Motor control equipment	ea	5	7,000	35,000	
Valves	ea	5	10,000	50,000	
Electrical accessories	ea	5	1,000	5,000	
Mechanical accessories	ea	5	1,000	5,000	
Discharge pipes	LS			44,500	
Crane	LS			40,000	
Miscellaneous metal work	LS			15,000	
Fish screen facility	LS			380,000	
Subtotal, Field Cost					$954,000
Calhoun Cut Pumping Plant to Denverton Creek (Mile 3.79 to Mile 7.00, 900 c.f.s.)					
Excavation	cy	1,362,000	$0.25	$340,500	
Trimming	lf	17,000	2.00	34,000	
Bridge, railroad	lf	140	750.00	105,000	
Bridge, county road	sf	4,800	12.00	57,600	
Traffic control	LS			40,000	
Regulation structures and transitions	LS			70,000	
Cross drainage control	LS			22,000	
Service road	sy	30,200	0.50	15,100	
Fence	mi	6.4	1,000	6,400	
Subtotal, Field Cost					$690,600
Denverton Creek to Cordelia Pumping Plant (Mile 7.00 to Mile 23.54, 680 c.f.s.)					
Excavation	cy	2,105,000	$0.40	$842,000	
Trimming	lf	86,700	1.00	86,700	
Suisun Slough siphon	LS			300,000	
U. S. Highway 40 siphon	LS			120,000	
Bridge, railroad, doubletrack	lf	80	1,500	120,000	
Bridge, railroad, singletrack	lf	100	750.00	75,000	
Bridge, State Highway 12	sf	3,520	10.00	35,200	
Bridge, county road	sf	4,200	12.00	50,400	
Bridge, county road (5)	sf	11,250	10.00	112,500	
Bridge, farm road (4)	sf	7,800	7.00	54,600	
Traffic control	LS			142,000	
Regulation structures and transitions	LS			50,000	
Cross drainage control	LS			178,000	
Drainage diversion channels	cy	800,000	0.25	200,000	
Service road	sy	155,400	0.50	77,700	
Fence	mi	33.0	1,000	33,000	
Subtotal, Field Cost					$2,477,100
Cordelia Pumping Plant (Mile 23.54, 500 c.f.s.)					
Structure	LS			$190,000	
Pumps, 100 c.f.s. (one standby unit)	ea	6	$35,000	210,000	
Motors, 1,500 horsepower	ea	6	40,500	243,000	
Motor control equipment	ea	6	12,000	72,000	
Valves	ea	6	7,200	43,200	
Electrical accessories	ea	6	6,000	36,000	
Mechanical accessories	ea	6	7,500	45,000	
Crane	LS			42,000	
Miscellaneous metal work	LS			9,500	
Subtotal, Field Cost					$890,700

ESTIMATED CAPITAL AND ANNUAL COSTS—NORTH BAY AQUEDUCT—Continued

Item	Unit	Quantity	Unit cost	Item cost	Amount
Cordelia Pumping Plant to Napa Siphon					
(Mile 23.54 to Mile 31.59, 500 c.f.s.)					
Discharge pipeline	lf	1,300	$207.00	$269,100	
Lined canal	lf	22,100	30.00	663,000	
Excavation, tunnel portal	cy	368,000	0.50	184,000	
Trimming, portal	sy	42,000	0.50	21,000	
Tunnel, 10-foot diameter	lf	18,900	262.00	4,951,800	
State Highway 29 siphon	lf	200	150.00	30,000	
Bridge, farm road (3)	sf	7,080	7.00	49,600	
Traffic control	LS			25,000	
Regulation structures and transitions	LS			210,000	
Cross drainage control	LS			20,000	
Service road	sy	34,000	0.50	17,000	
Fence	mi	8.4	1,000	8,400	
Subtotal, Field Cost					$6,448,900
Napa Siphon					
(Mile 31.59 to Mile 34.03, 420 c.f.s.)					
Concrete pipe, 10-foot dia.	lf	12,500	$110.00	$1,375,000	
Concrete pipe, 10-foot dia., underwater	lf	400	410.00	164,000	
Subtotal, Field Cost					$1,539,000
Napa Siphon to Sonoma Siphon					
(Mile 34.03 to Mile 40.55, 400 c.f.s.)					
Lined canal	lf	31,800	$26.00	$826,800	
Concrete pipe, 10-foot dia.	lf	2,600	110.00	286,000	
Bridge, county road (2)	sf	1,800	10.00	18,000	
Bridge, farm road (3)	sf	2,640	7.00	18,500	
Traffic control	LS			9,000	
Regulation structures and transitions	LS			80,000	
Cross drainage control	LS			15,000	
Service road	sy	50,000	0.50	25,000	
Fence	mi	12.2	1,000	12,200	
Subtotal, Field Cost					$1,290,500
Sonoma Siphon					
(Mile 40.55 to Mile 43.50, 290 c.f.s.)					
Concrete pipe, 9-foot dia.	lf	15,300	$100.00	$1,530,000	
Concrete pipe, 9-foot dia., underwater	lf	300	400.00	120,000	
Subtotal, Field Cost					$1,650,000
Sonoma Siphon to Petaluma Siphon					
(Mile 43.50 to Mile 54.07, 280 c.f.s.)					
Lined canal	lf	13,200	$24.00	$316,800	
Lined canal	lf	39,100	22.00	860,200	
Concrete pipe, 9-foot dia.	lf	2,300	100.00	230,000	
State Highway 37 siphon (4)	lf	1,200	100.00	120,000	
Bridge, farm road (4)	sf	2,880	7.00	20,100	
Traffic control	LS			35,000	
Regulation structures and transitions	LS			70,000	
Cross drainage control	LS			28,000	
Service road	sy	110,000	0.50	55,000	
Fence	mi	20.1	1,000	20,100	
Subtotal, Field Cost					$1,755,200
Petaluma Siphon to Novato Reservoir					
(Mile 54.07 to Mile 59.28, 100 c.f.s.)					
Concrete pipe, 6-foot dia.	lf	14,000	$55.00	$770,000	
Concrete pipe, 6-foot dia., underwater	lf	800	300.00	240,000	
Lined canal	lf	12,700	17.00	215,900	
Cross drainage control	LS			4,000	
Service road	sy	16,200	0.50	8,100	
Fence	mi	4.9	1,000	4,900	
Subtotal, Field Cost					$1,242,900

ESTIMATED CAPITAL AND ANNUAL COSTS—NORTH BAY AQUEDUCT—Continued

Item	Unit	Quantity	Unit cost	Item cost	Amount
Novato Dam and Reservoir					
Crest elevation: 40 feet, m.s.l.					
Spillway crest elevation: 32 feet, m.s.l.					
Streambed elevation: 3 feet, m.s.l.					
Reservoir capacity: 570 acre-feet					
Dam					
Stripping	cy	41,600	$0.65	$27,000	
Embankment					
Impervious	cy	40,400	0.60	24,200	
Pervious	cy	42,900	0.80	34,300	
Spillway					
Excavation	cy	11,000	0.80	8,800	
Concrete	cy	665	81.00	53,800	
Reinforcing steel	lb	53,200	0.15	8,000	
Gates	LS			1,500	
Outlet works	LS			8,500	
Inlet structure	LS			9,900	
County road relocation	lf	2,700	12.50	33,800	
Fence	lf	7,500	2.00	15,000	
Subtotal, Field Cost					$224,800
Total, Field Cost					$19,323,700
Contingencies, 15 per cent					$2,896,300
Subtotal					$22,220,000
Engineering and administration, 10 per cent					$2,220,000
Subtotal					$24,440,000
Interest during construction[1]					$1,100,000
Total, Estimated Construction Cost					$25,540,000
Rights of Way					
Lindsay Slough to Calhoun Cut Pumping Plant				None	
Calhoun Cut Pumping Plant to Denverton Creek	ac	115	$200.00	$23,000	
Denverton Creek to Cordelia Pumping Plant	ac	54	2,000	108,000	
	ac	153	500.00	76,500	
	ac	214	200.00	42,800	
Cordelia Pumping Plant to Napa Siphon	ac	13	1,500	19,500	
	ac	91	1,000	91,000	
	ac	5	200.00	1,000	
Napa Siphon	ac	30	500.00	15,000	
Napa Siphon to Sonoma Siphon	ac	115	700.00	80,500	
Sonoma Siphon	ac	38	500.00	19,000	
Sonoma Siphon to Petaluma Siphon	ac	224	700.00	156,800	
Petaluma Siphon to Novato Reservoir	ac	35	2,000	70,000	
	ac	40	1,000	40,000	
Novato Dam and Reservoir	ac	70	4,000	280,000	
Subtotal, Rights of Way					$1,023,100
Acquisition of rights of way					$196,900
Total, Rights of Way					$1,220,000
TOTAL ESTIMATED CAPITAL COST					$26,760,000
ANNUAL COSTS					
Interest					$802,800
Sinking fund amortization					237,200
Replacement					59,300
Operation and maintenance					258,700
Electrical energy					153,000
General expense					82,000
TOTAL ESTIMATED ANNUAL EQUIVALENT COST					$1,593,000

[1] At 3 percent for one-half of a three-year construction period.

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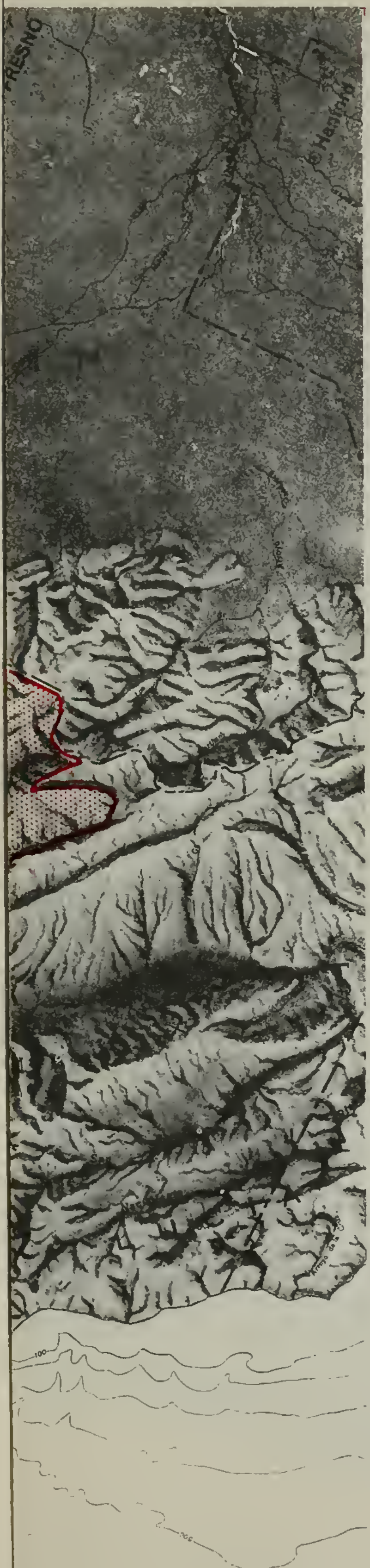

LEGEND

BOUNDARY OF AREA OF INVESTIGATION

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

AREA OF INVESTIGATION

MARCH 1957

SCALE OF MILES

8 0 8 16 24

LEGEND

BOUNDARY OF AREA OF INVESTIGATION

STATE OF CALIFORNIA
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AREA OF INVESTIGATION

MARCH 1957

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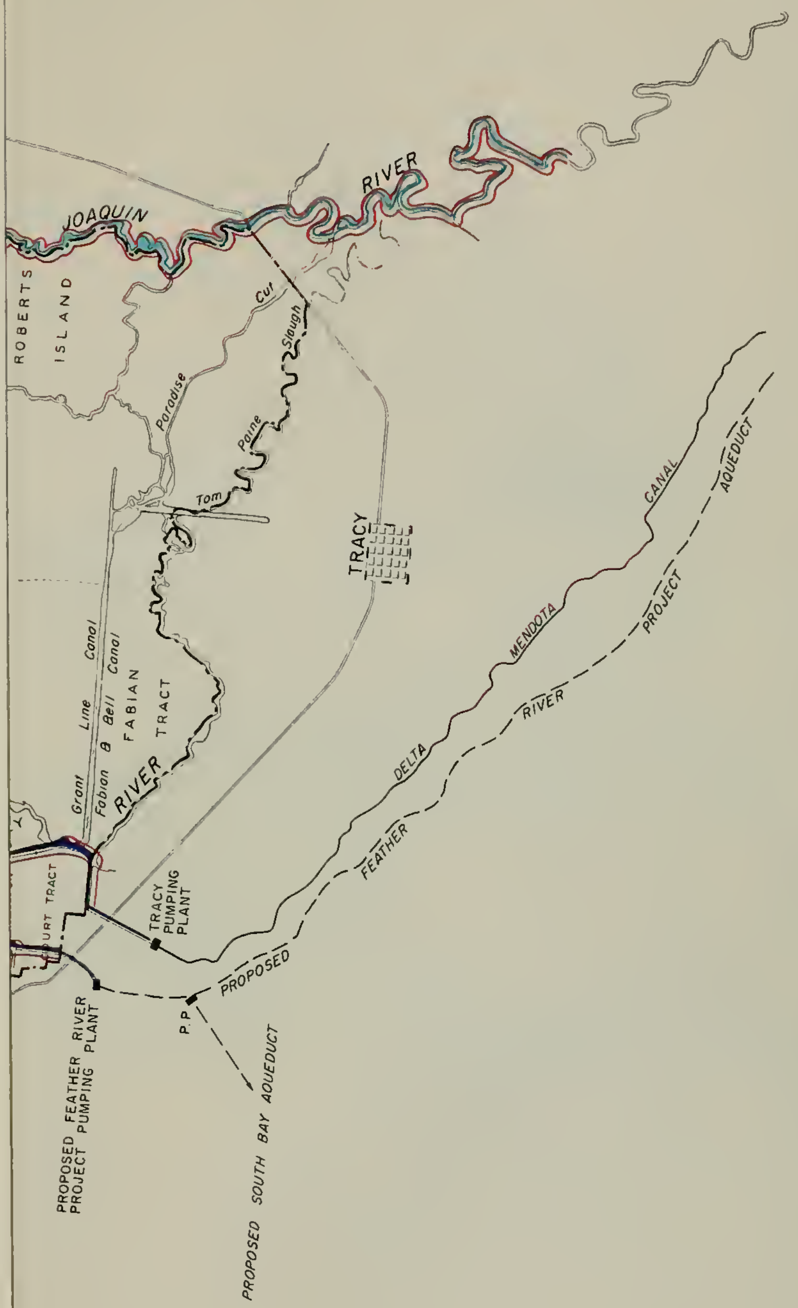

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SALINITY CONTROL BARRIER INVESTIGATION

JUNCTION POINT BARRIER AND DELTA FLOOD CONTROL PLAN

MARCH 1957

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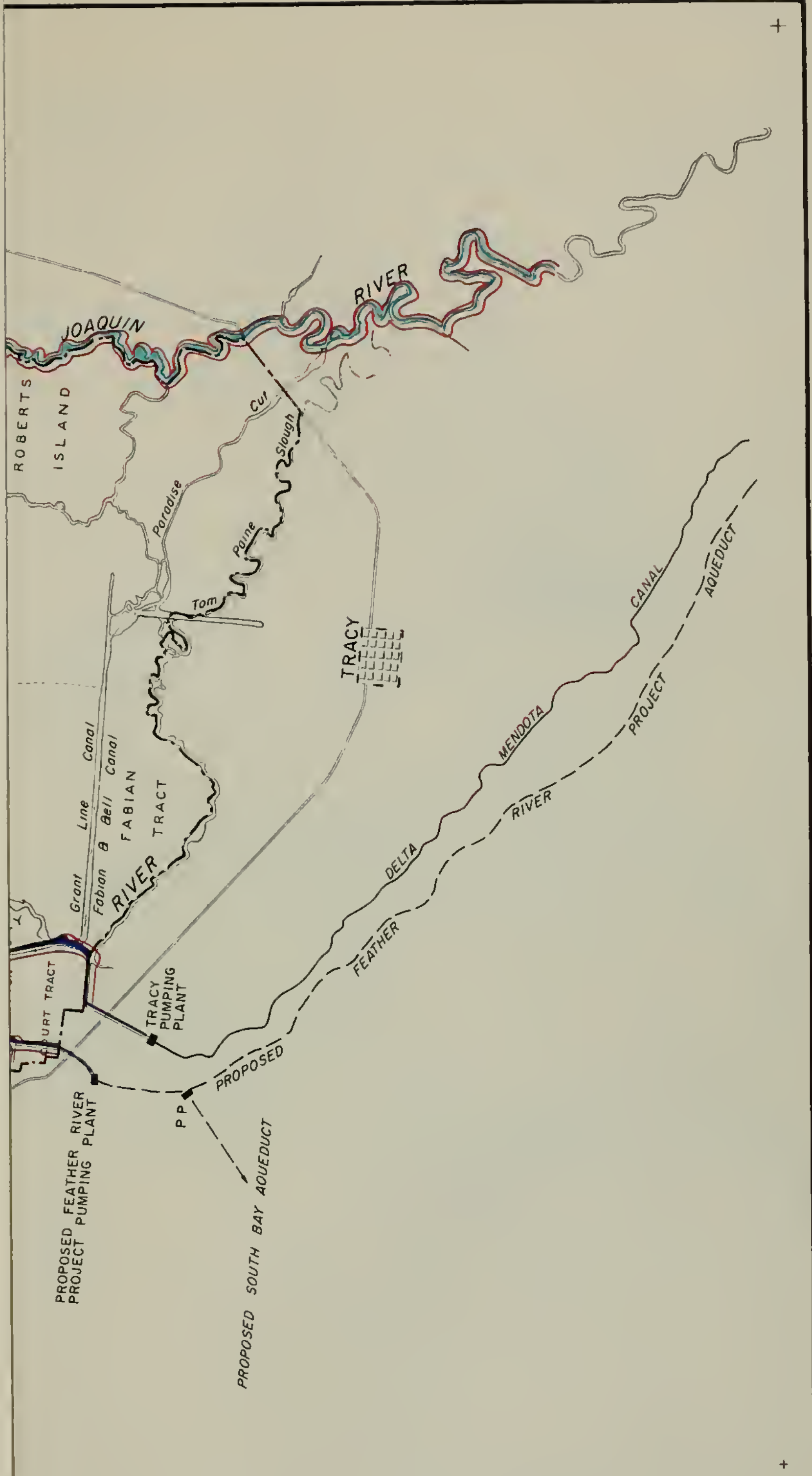

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JUNCTION POINT BARRIER
AND
DELTA FLOOD CONTROL PLAN
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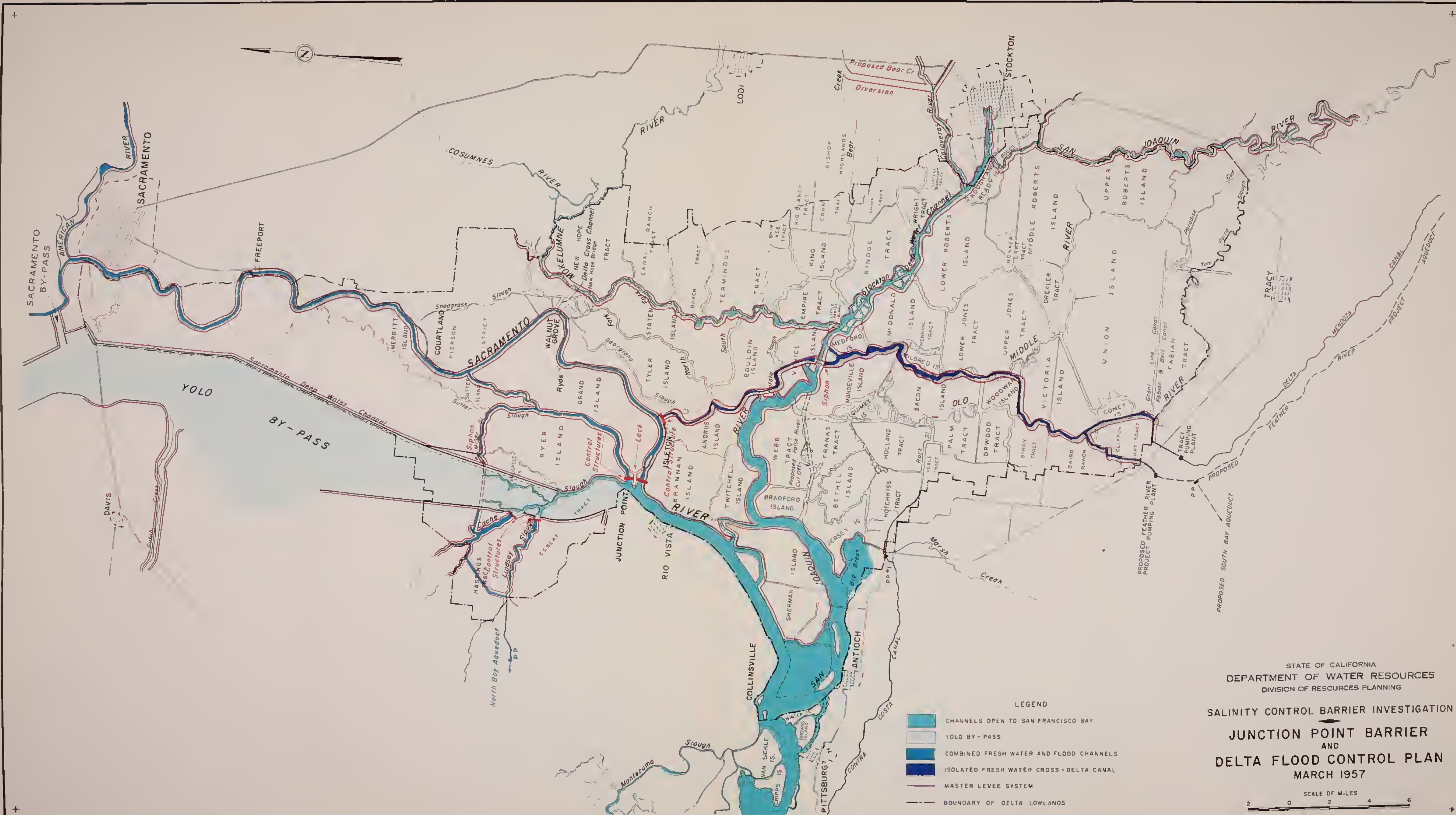

LEGEND

- CHANNELS OPEN TO SAN FRANCISCO BAY
- YOLO BY-PASS
- COMBINED FRESH WATER AND FLOOD CHANNELS
- ISOLATED FRESH WATER CROSS-DELTA CANAL
- MASTER LEVEE SYSTEM
- BOUNDARY OF DELTA LOWLANDS

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JUNCTION POINT BARRIER AND DELTA FLOOD CONTROL PLAN

MARCH 1957

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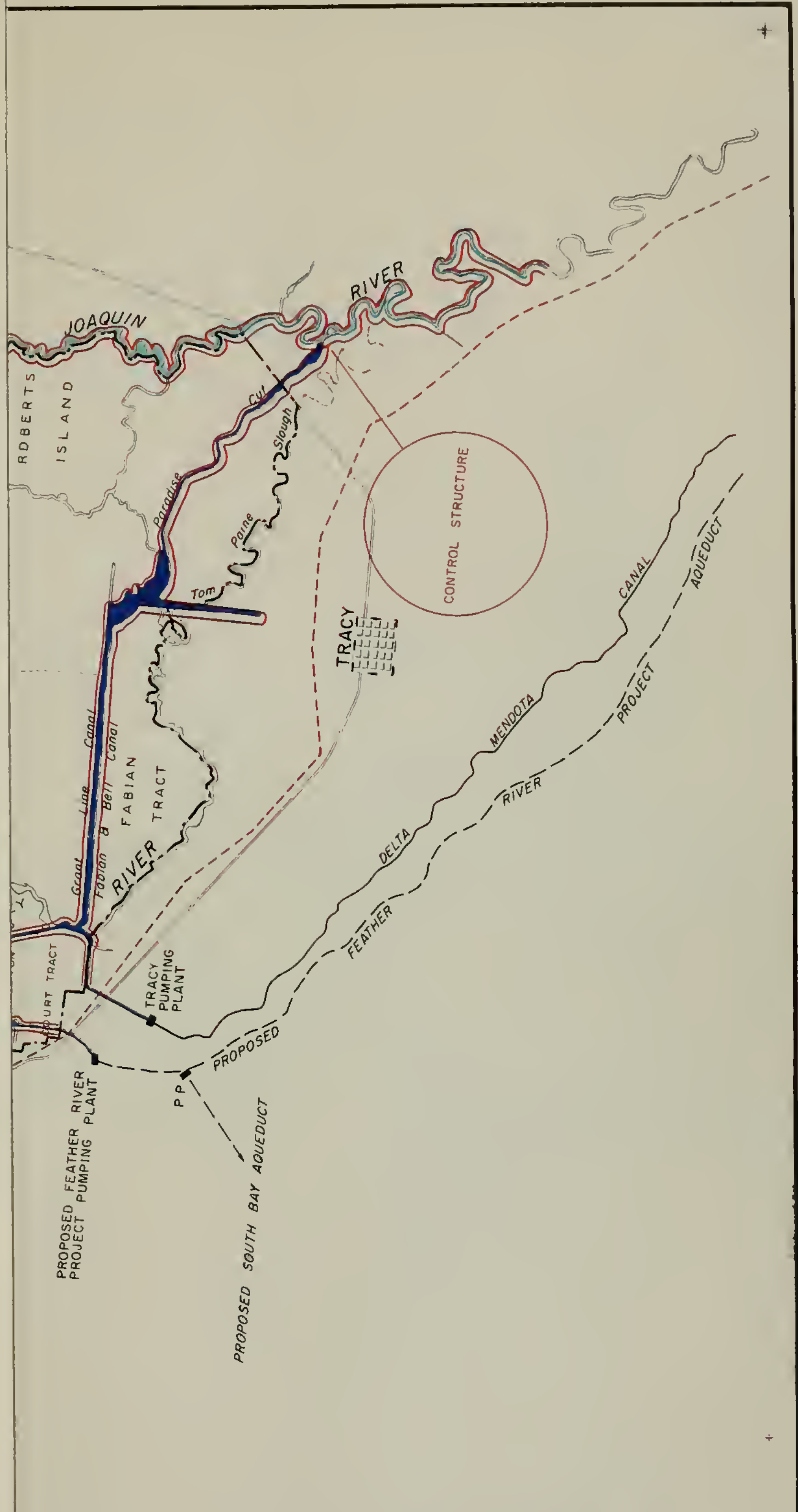

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SALINITY CONTROL BARRIER INVESTIGATION

BIEMOND PLAN
MARCH 1957

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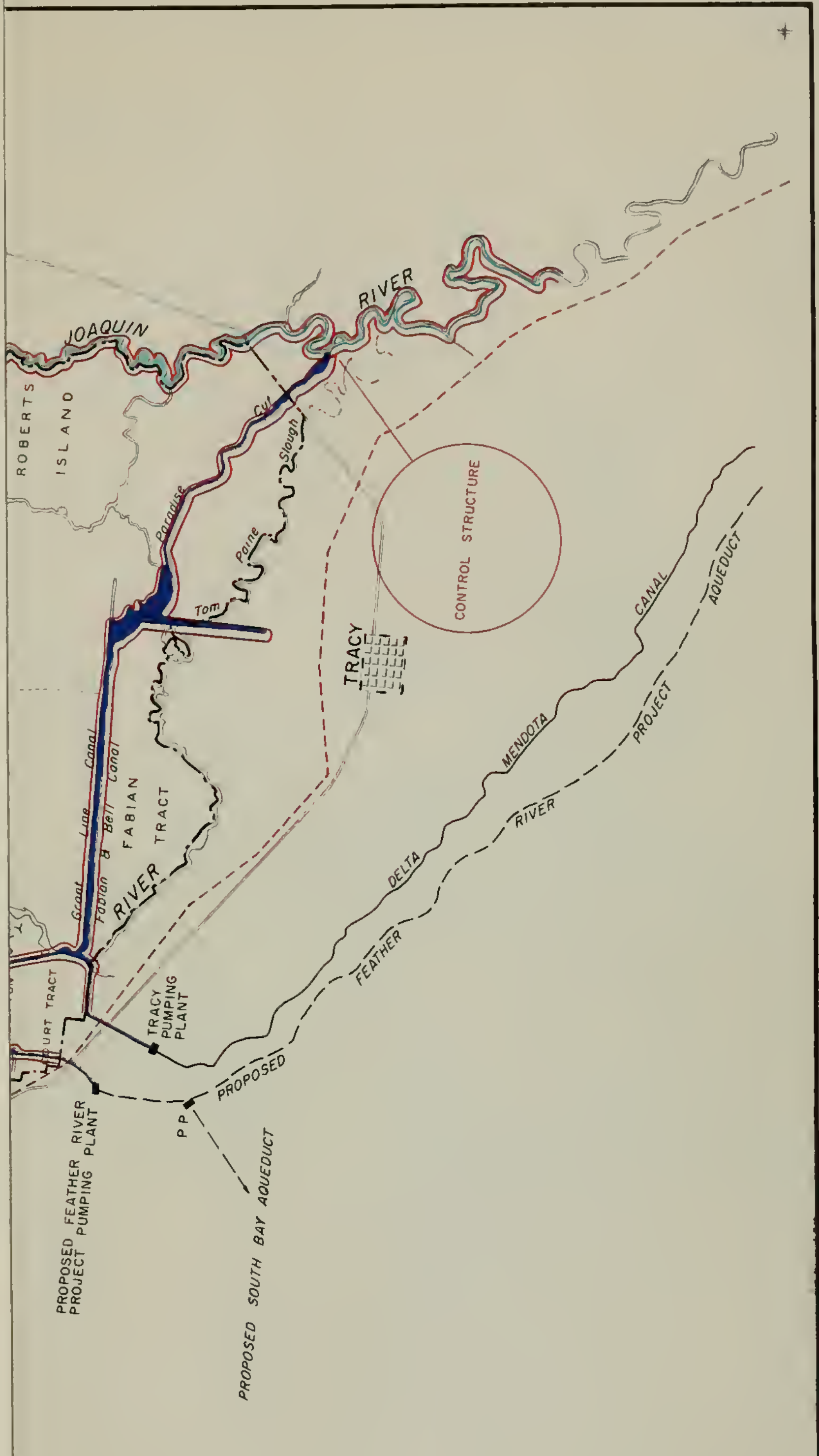

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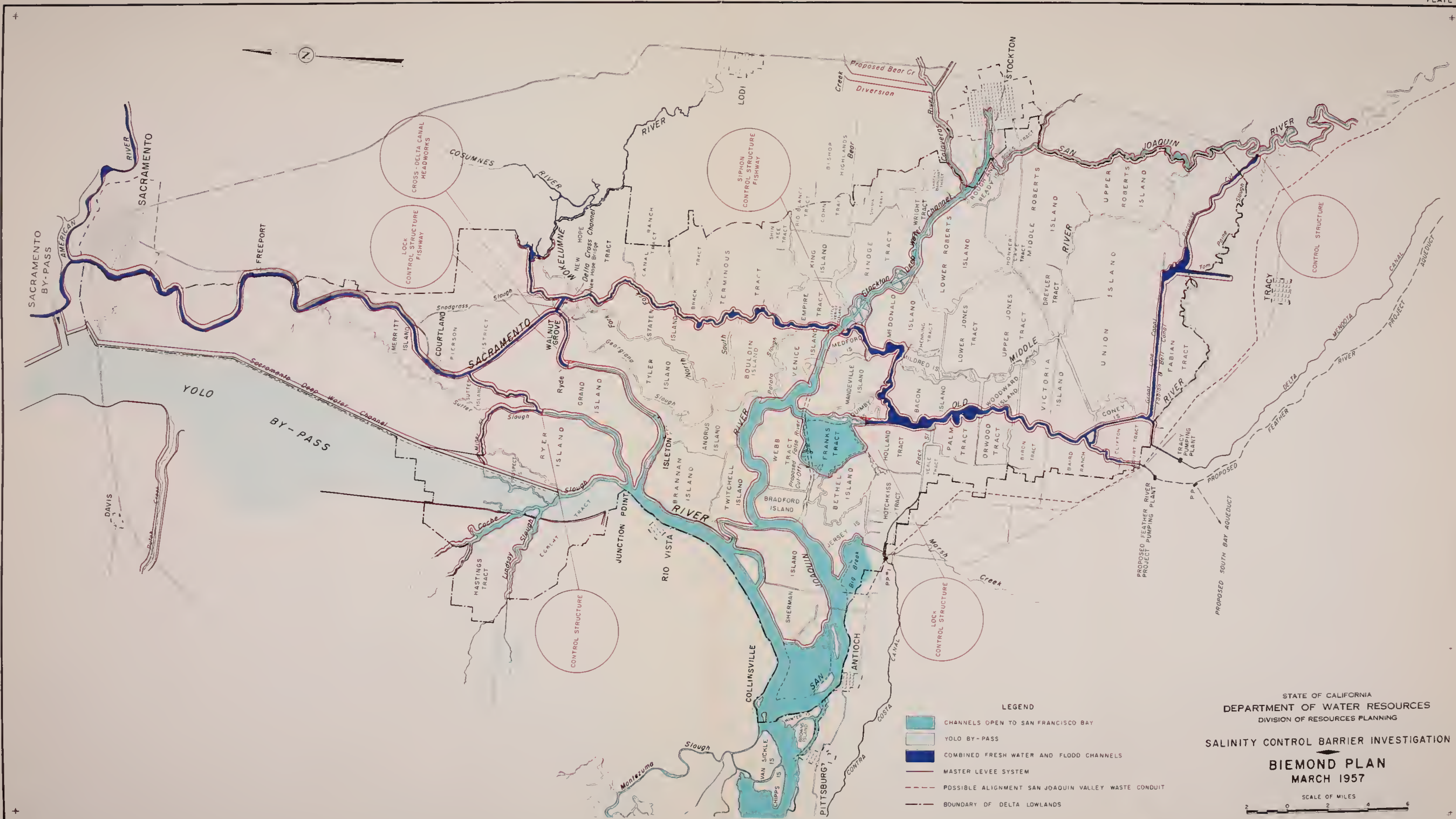
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SALINITY CONTROL BARRIER INVESTIGATION
BIEMOND PLAN
MARCH 1957
SCALE OF MILES
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LEGEND
CHANNELS OPEN TO SAN FRANCISCO BAY
YOLO BY-PASS
COMBINED FRESH WATER AND FLOOD CHANNELS
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POSSIBLE ALIGNMENT SAN JOAQUIN VALLEY WASTE CONDUIT
BOUNDARY OF DELTA LOWLANDS
CROSS-DELTA CANAL HEADWORKS
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SIPHON CONTROL STRUCTURE FISHWAY
CONTROL STRUCTURE
CONTROL STRUCTURE
LOCK CONTROL STRUCTURE
SACRAMENTO BY-PASS
AMERICAN RIVER
SACRAMENTO
FREEPORT
COSUMNES RIVER
MOKELUMNE RIVER
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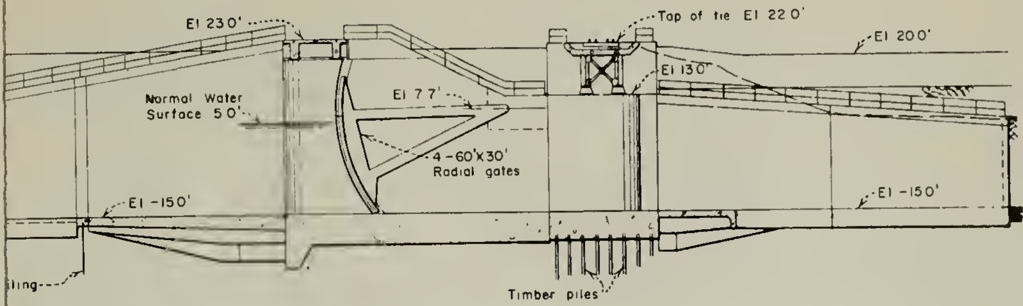
Proposed Bear Cr Diversion
STOCKTON
SAN JOAQUIN RIVER
TRACY
TRACY PUMPING PLANT
PROPOSED FEATHER RIVER PROJECT PUMPING PLANT
PROPOSED SOUTH BAY AQUEDUCT
DELTA MENDOTA CANAL
FEATHER RIVER PROJECT AQUEDUCT
YOLO BY-PASS
Sacramento Deep Water Channel
DAVIS
COURTLAND
WALNUT GROVE
Ryde
ISLETON
RIO VISTA
JUNCTION POINT
COLLINSVILLE
ANTIOCH
PITTSBURG
CONTRA COSTA CANAL
Montezuma Slough
Marsh Creek
MERRITT ISLAND
PIERSON DISTRICT
SUTTER ISLAND
GRAND ISLAND
RYER ISLAND
HASTINGS TRACT
TYLER ISLAND
STATEN ISLAND
ANDRUS ISLAND
BRANNAN ISLAND
TWITCHELL ISLAND
BOULDIN ISLAND
VENICE ISLAND
WEBB TRACT
FRANKS TRACT
BRADFORD ISLAND
BETHEL ISLAND
SHERMAN ISLAND
JERSEY IS
HOLLAND TRACT
HOTCHKISS TRACT
MANDEVILLE ISLAND
MEDFORD IS
BACON ISLAND
PALM TRACT
ORWOOD TRACT
WOODWARD ISLAND
VICTORIA ISLAND
UNION ISLAND
FABIAN TRACT
CONEY IS
MCDONALD ISLAND
LOWER JONES TRACT
UPPER JONES TRACT
LOWER ROBERTS ISLAND
MIDDLE ROBERTS ISLAND
UPPER ROBERTS ISLAND
EMPIRE TRACT
KING ISLAND
TERMINOUS TRACT
RINDGE TRACT
WRIGHT TRACT
BISHOP TRACT
NEW HOPE TRACT
CANAL RANCH TRACT
DREYLER TRACT
MILDRED IS
QUIMBY IS
VAN SICKLE IS
CHIPPS IS
WINTER IS
Stockton Deep Water Channel
MIDDLE RIVER
OLD RIVER
Georgiana Slough
Delta Cross Channel
Cache Slough
Lindsey Slough
Snodgrass Slough



SS-DELTA CANAL HEADWORKS

SCALE OF FEET
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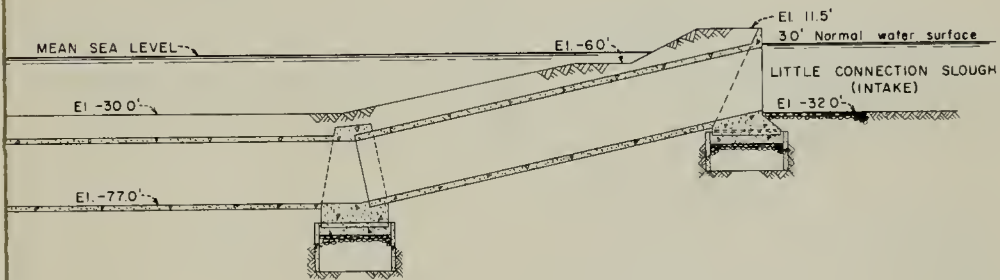

)F FRESH WATER SIPHON

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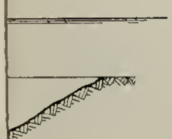

NOTE ELEVATIONS REFER TO SEA LEVEL DATUM OF 1929

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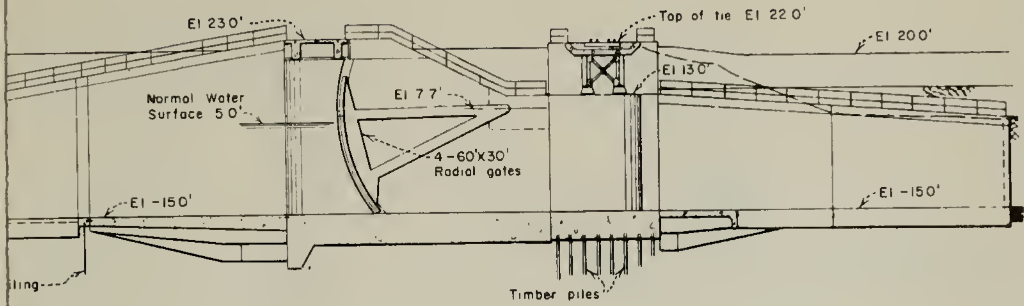
SALINITY CONTROL BARRIER INVESTIGATION

LAYOUT OF PRINCIPAL STRUCTURES
BIEMOND PLAN
MARCH 1957

SCALE AS SHOWN



SS-DELTA CANAL HEADWORKS

SCALE OF FEET
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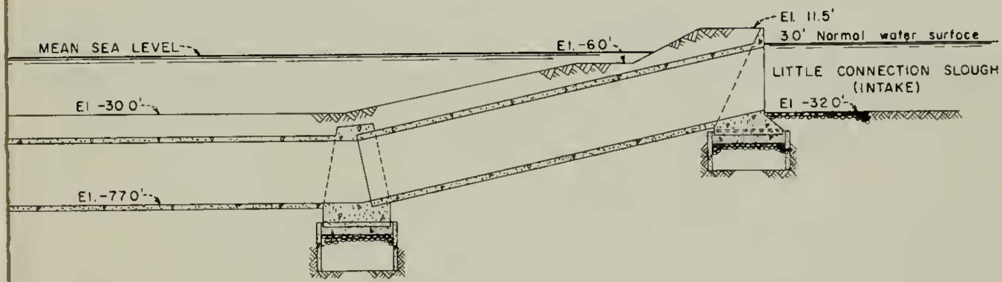

F FRESH WATER SIPHON

SCALE OF FEET
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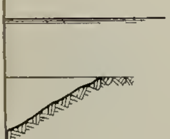
NOTE ELEVATIONS REFER TO SEA LEVEL DATUM OF 1929



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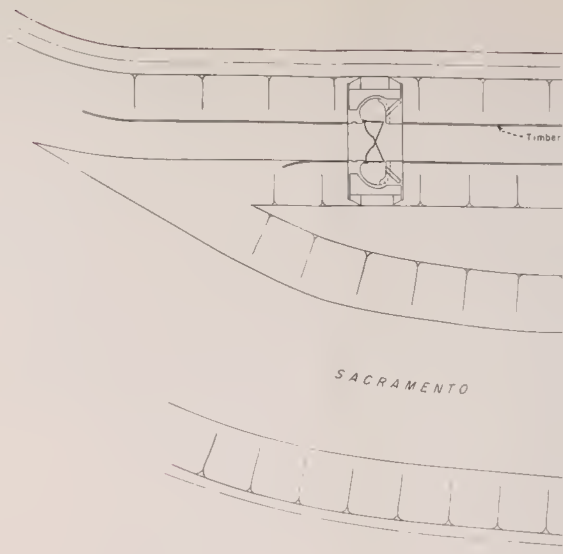
DIVISION OF RESOURCES PLANNING

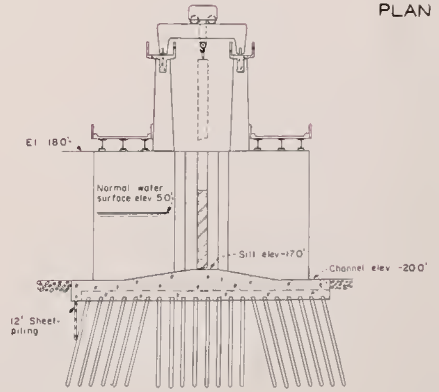
SALINITY CONTROL BARRIER INVESTIGATION

LAYOUT OF PRINCIPAL STRUCTURES
BIEMOND PLAN
MARCH 1957

SCALE AS SHOWN

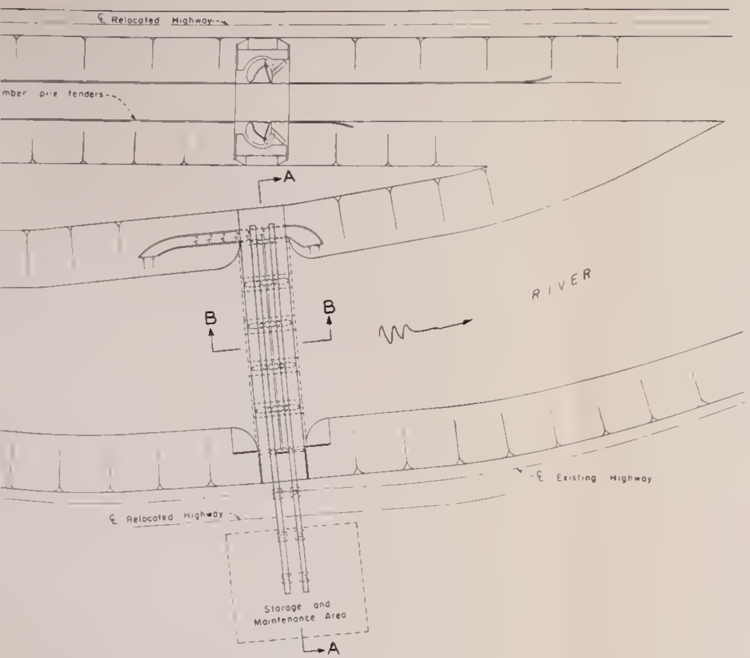


PLAN OF CONTROL ST



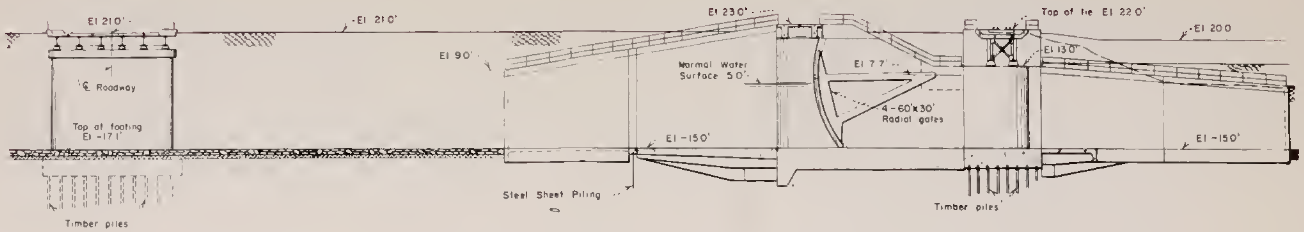
SECTION B-B OF CONTROL STRUCTURE
SACRAMENTO RIVER AT RYDE

SCALE OF FEET
20 0 20 40 60



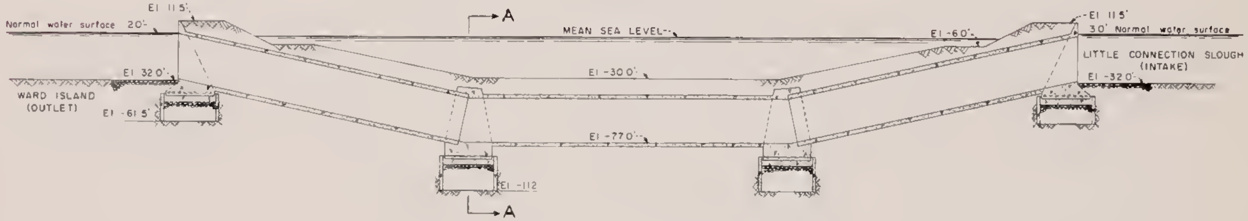
STRUCTURE, FISHWAY AND LOCK

SCALE OF FEET
0 100 200 300



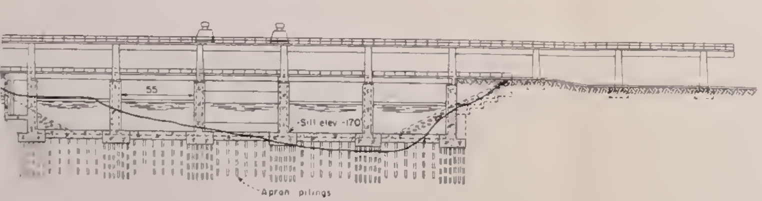
PROFILE OF CROSS-DELTA CANAL HEADWORKS

SCALE OF FEET
20 0 20 40 60



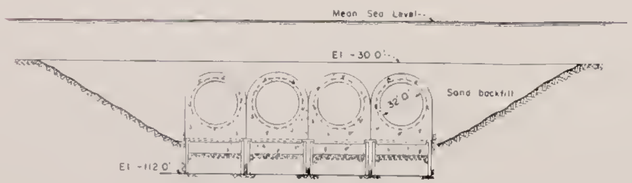
PROFILE OF FRESH WATER SIPHON

SCALE OF FEET
50 0 50 100 150



SECTION A-A OF CONTROL STRUCTURE
SACRAMENTO RIVER AT RYDE

SCALE OF FEET
50 0 50 100 150



SECTION A-A OF FRESH WATER SIPHON

SCALE OF FEET
50 0 50 100 150

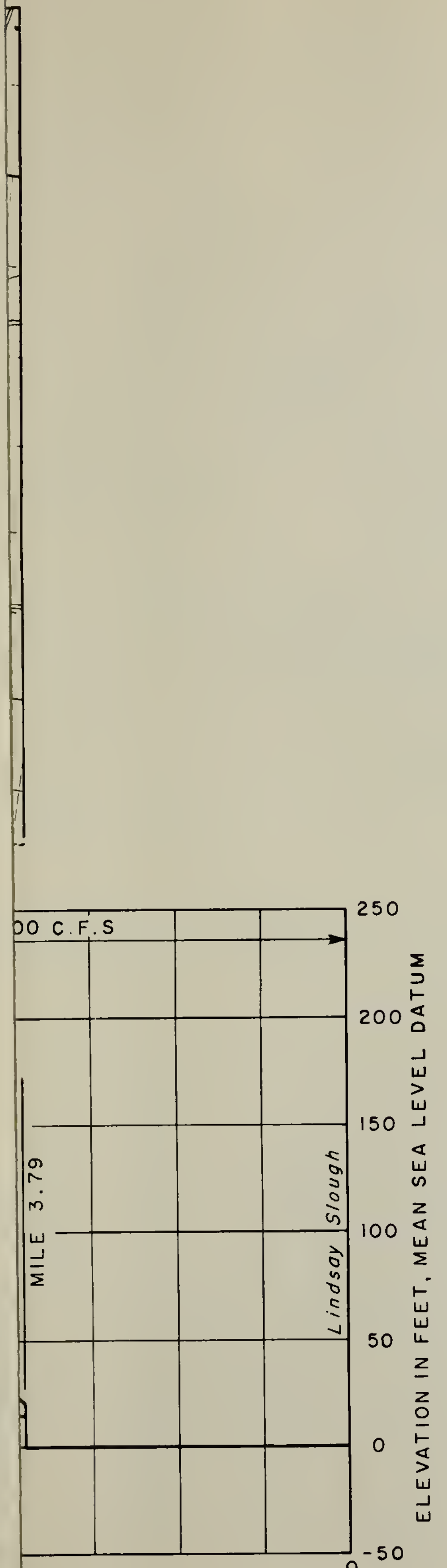
NOTE: ELEVATIONS REFER TO SEA LEVEL DATUM OF 1929

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

LAYOUT OF PRINCIPAL STRUCTURES
BIEMOND PLAN
MARCH 1957

SCALE AS SHOWN

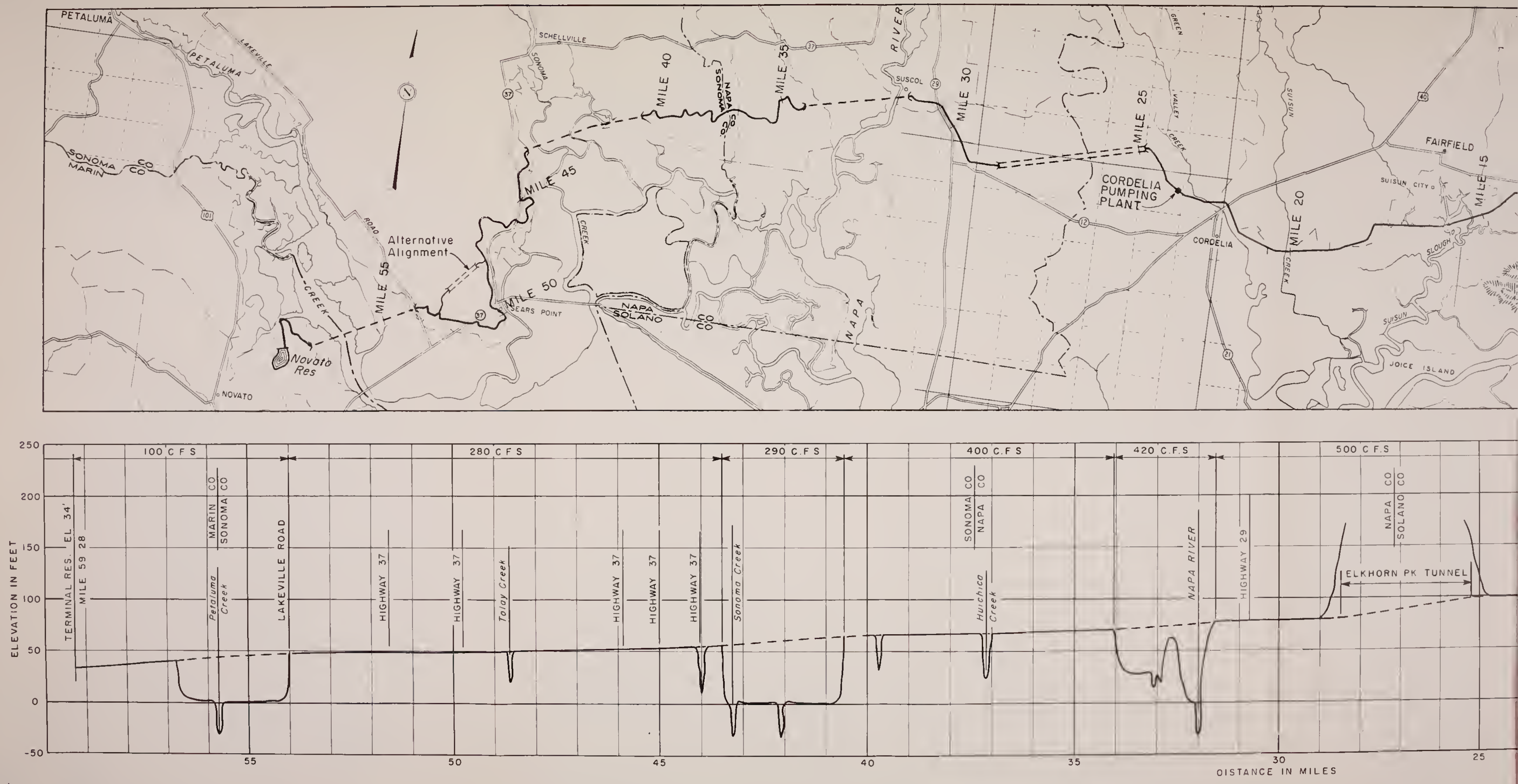


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

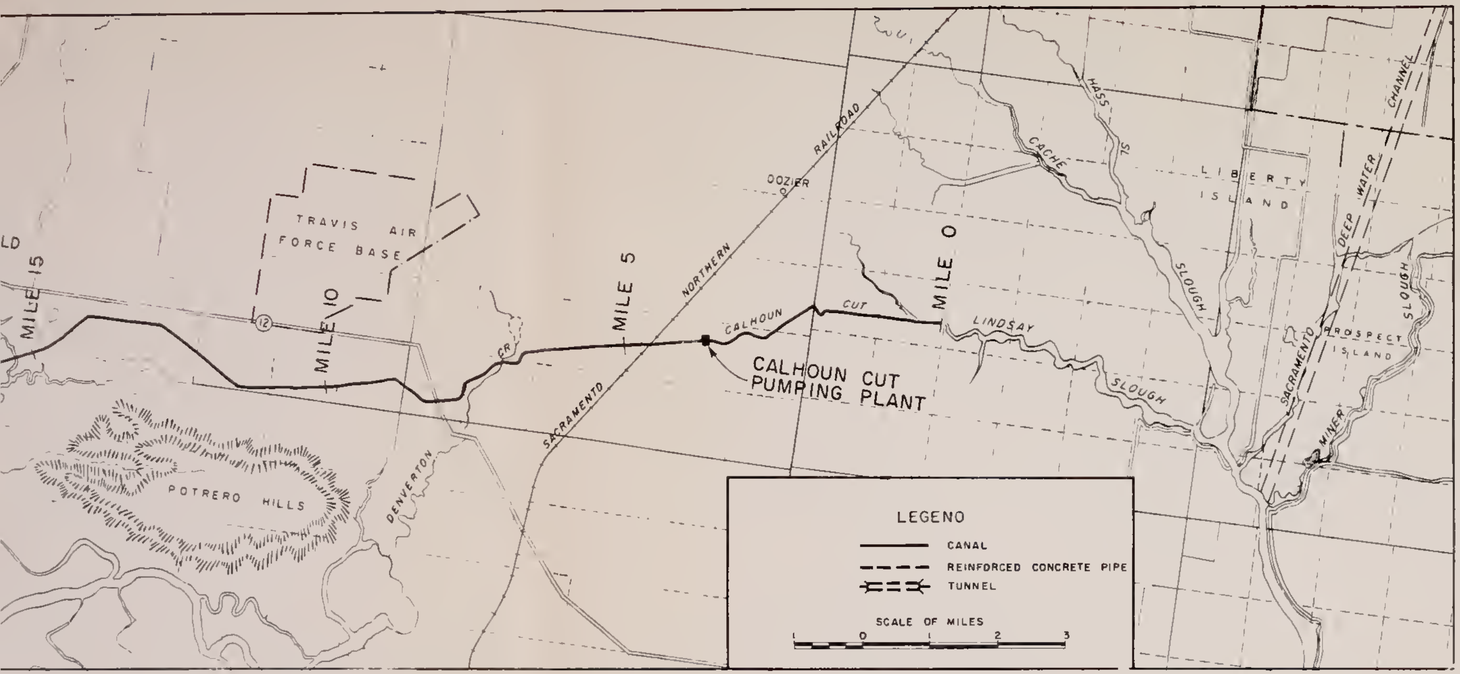
SALINITY CONTROL BARRIER INVESTIGATION

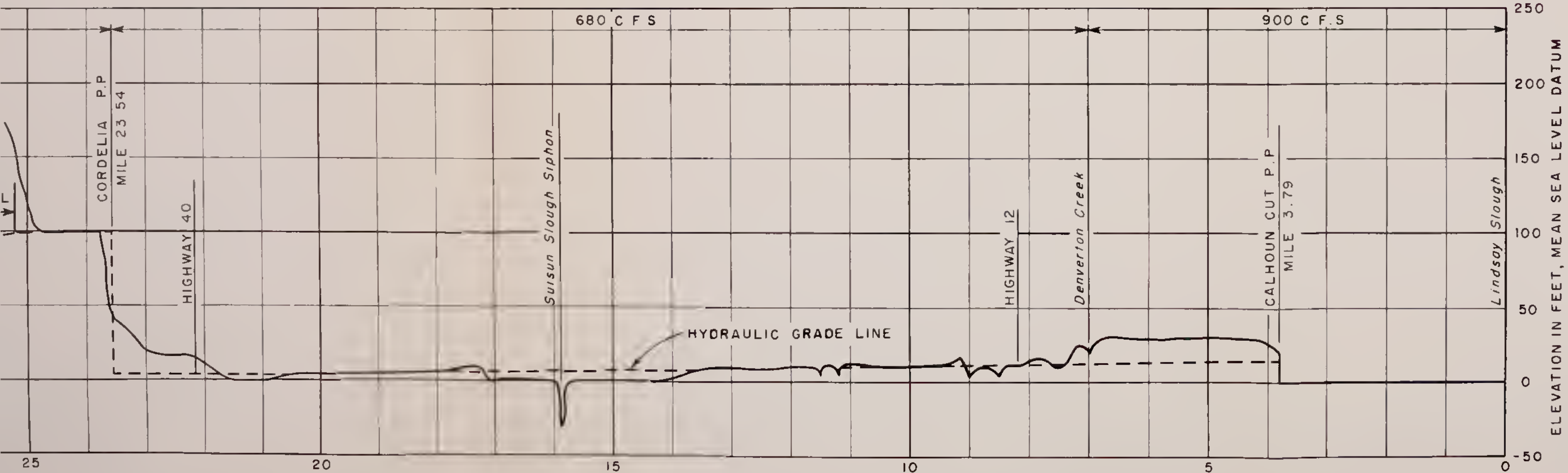
NORTH BAY AQUEDUCT
MARCH 1957

SCALE AS SHOWN



PETALUMA
LAKEVILLE
PETALUMA
SCHELLVILLE
SONOMA
MILE 40
SONOMA
NAPA CO
MILE 35
RIVER
SUSCOL
MILE 30
GREEN
VALLEY
CREEK
MILE 25
SUISUN
FAIRFIELD
MILE 15
SONOMA CO
MARIN CO
MILE 45
CORDELIA PUMPING PLANT
SUISUN CITY
MILE 20
ROAD
Alternative Alignment
CREEK
CORDELIA
SLOUGH
CREEK
MILE 55
CREEK
MILE 50
SEARS POINT
NAPA CO
SOLANO CO
NAPA
SUISUN
Novato Res
JOICE ISLAND
NOVATO
100 C F S
280 C F S
290 C.F.S
400 C.F.S
420 C.F.S
500 C.F.S
ELEVATION IN FEET
TERMINAL RES. EL 34'
MILE 59.28
MARIN CO
SONOMA CO
Petaluma Creek
LAKEVILLE ROAD
HIGHWAY 37
HIGHWAY 37
Tolay Creek
HIGHWAY 37
HIGHWAY 37
HIGHWAY 37
Sonoma Creek
SONOMA CO
NAPA CO
Huichica Creek
NAPA RIVER
HIGHWAY 29
NAPA CO
SOLANO CO
ELKHORN PK TUNNEL
250
200
150
100
50
0
-50
55
50
45
40
35
30
25
DISTANCE IN MILES





STATE OF CALIFORNIA
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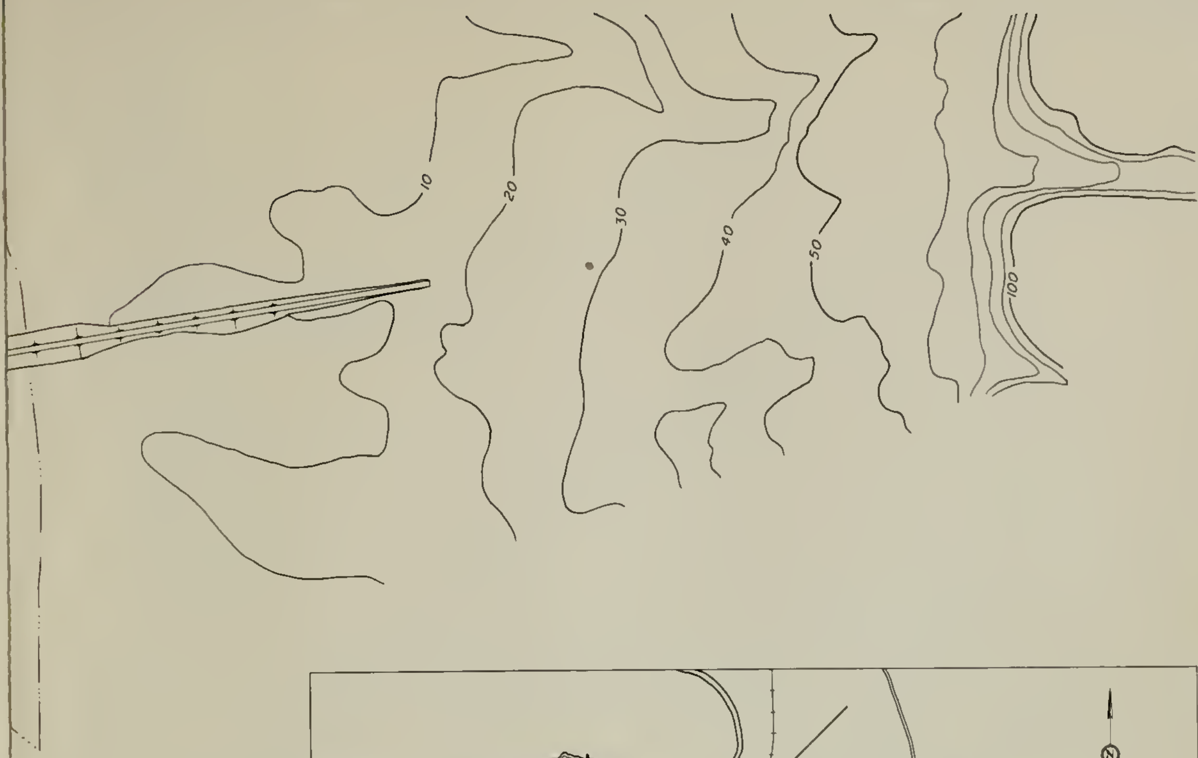
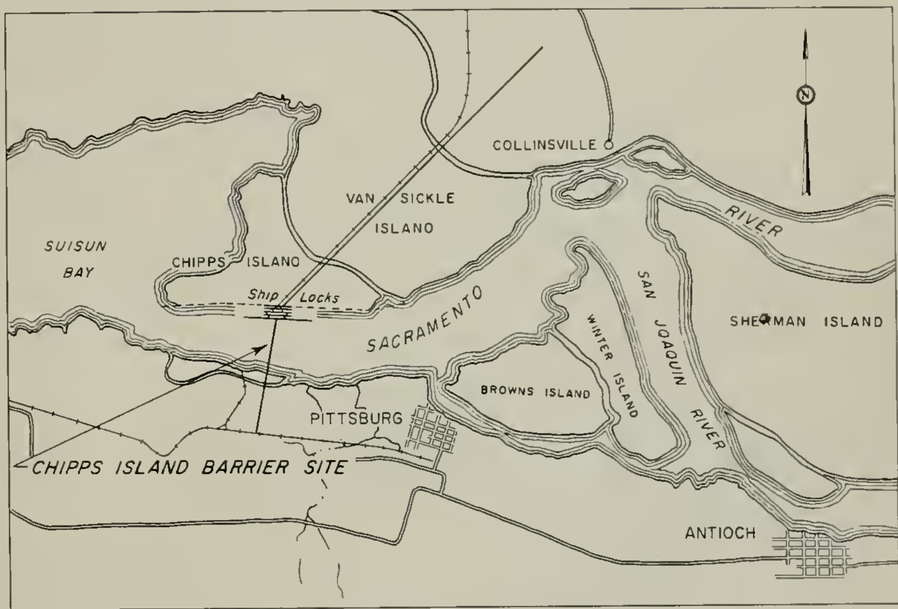
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

NORTH BAY AQUEDUCT
MARCH 1957

SCALE AS SHOWN





LOCATION MAP

SCALE OF MILES

1 0 1 2

El -20'

...t Deck El 63'

Top of Pier El 10'

M.S.L

— Stop Log Guides

— Fixed Wheel, Vertical Lift Steel Gate 48' x 60'

Gate Sill El. – 40'

Floodway Channel Floor El. – 43'

Gravel

Sand

Timber Piles

...DWAY STRUCTURE

100

NOTE ELEVATIONS REFER TO SEA LEVEL DATUM OF 1929

STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

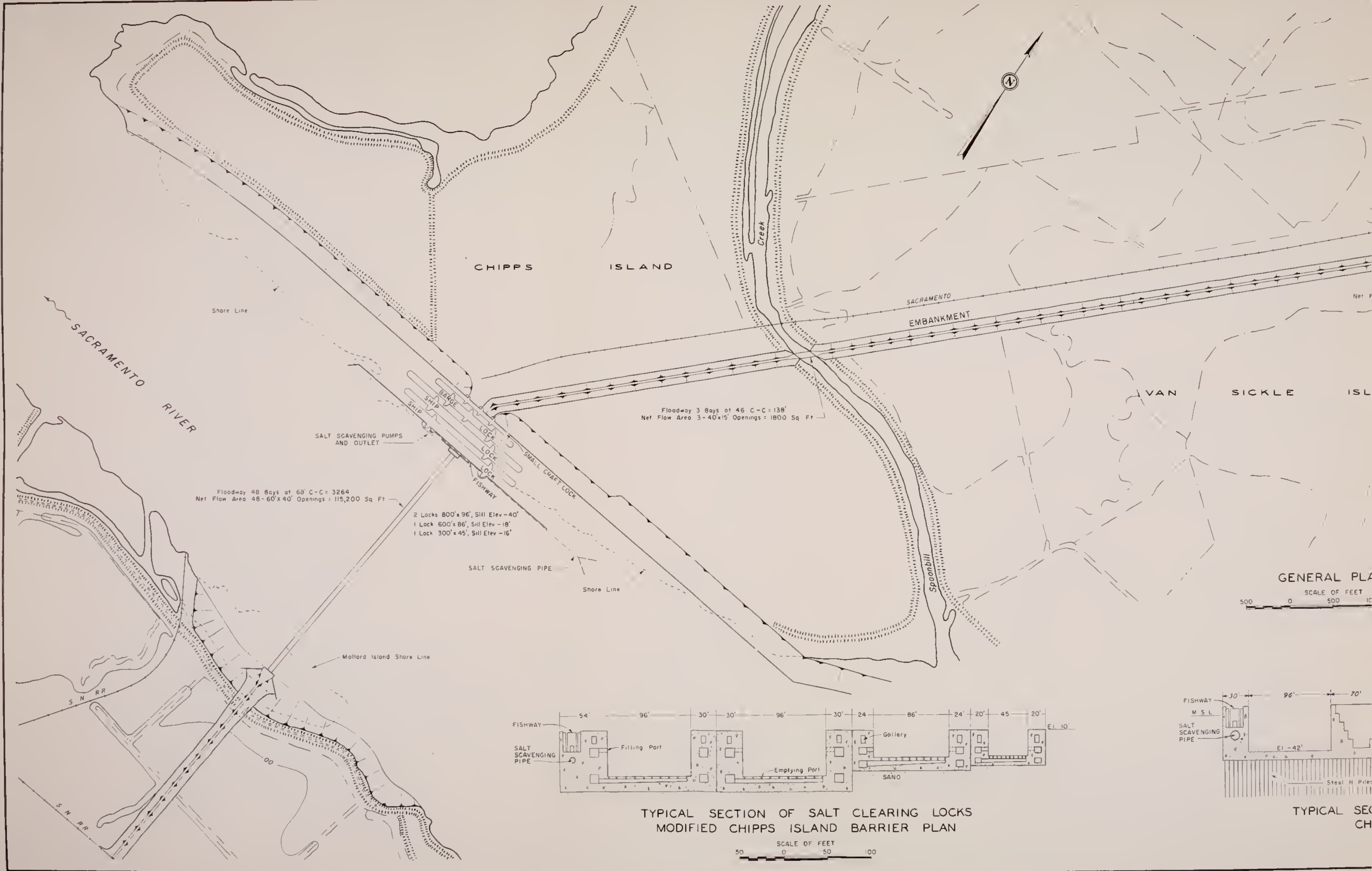
LAYOUT OF PRINCIPAL STRUCTURES

CHIPPS ISLAND BARRIER PLANS

MARCH 1957

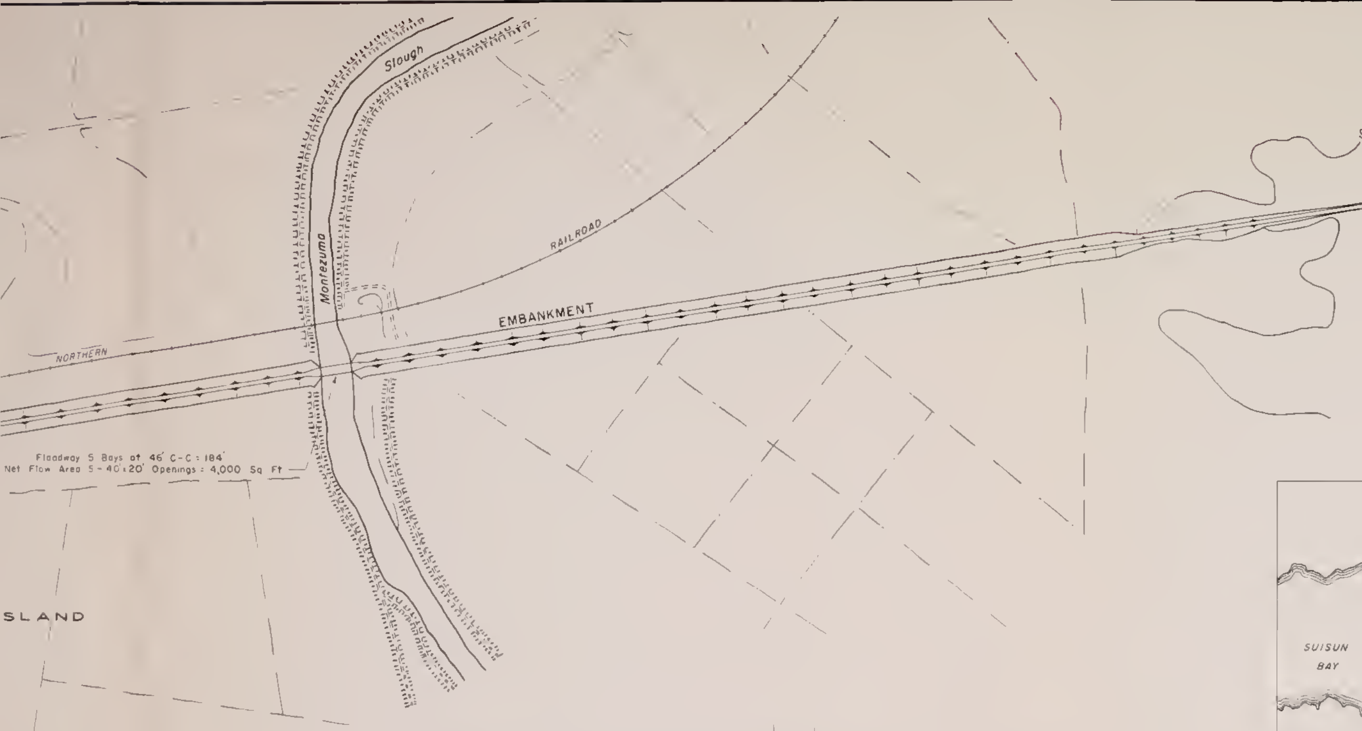
SCALE AS SHOWN

51344-C



TYPICAL SECTION OF SALT CLEARING LOCKS
MODIFIED CHIPPS ISLAND BARRIER PLAN

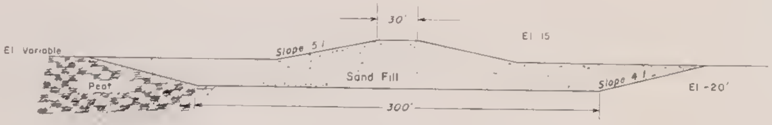
SCALE OF FEET
50 0 50 100



PLAN

ET

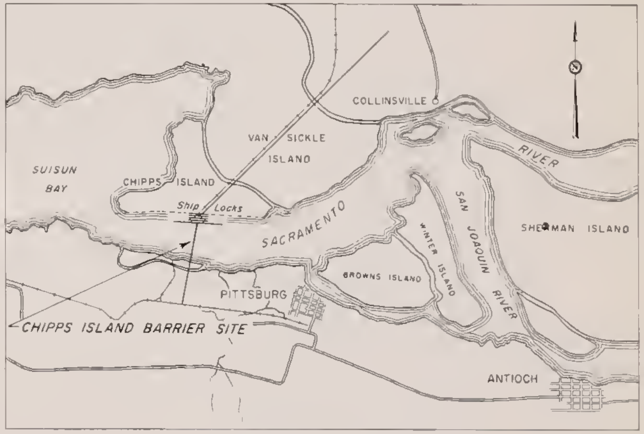
1000 1500



TYPICAL SECTION OF EMBANKMENT

SCALE OF FEET

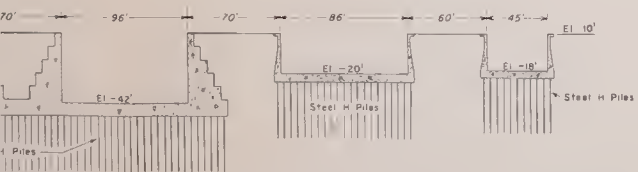
50 0 50 100



LOCATION MAP

SCALE OF MILES

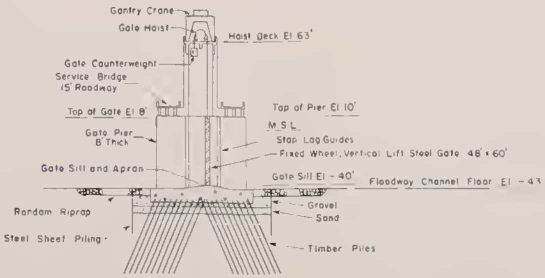
0 1 2



SECTION OF CONVENTIONAL SHIP LOCKS
CHIPPS ISLAND BARRIER PLAN

SCALE OF FEET

50 0 50 100



TYPICAL SECTION OF FLOODWAY STRUCTURE

SCALE OF FEET

50 0 50 100

NOTE ELEVATIONS REFER TO SEA LEVEL DATUM OF 1929

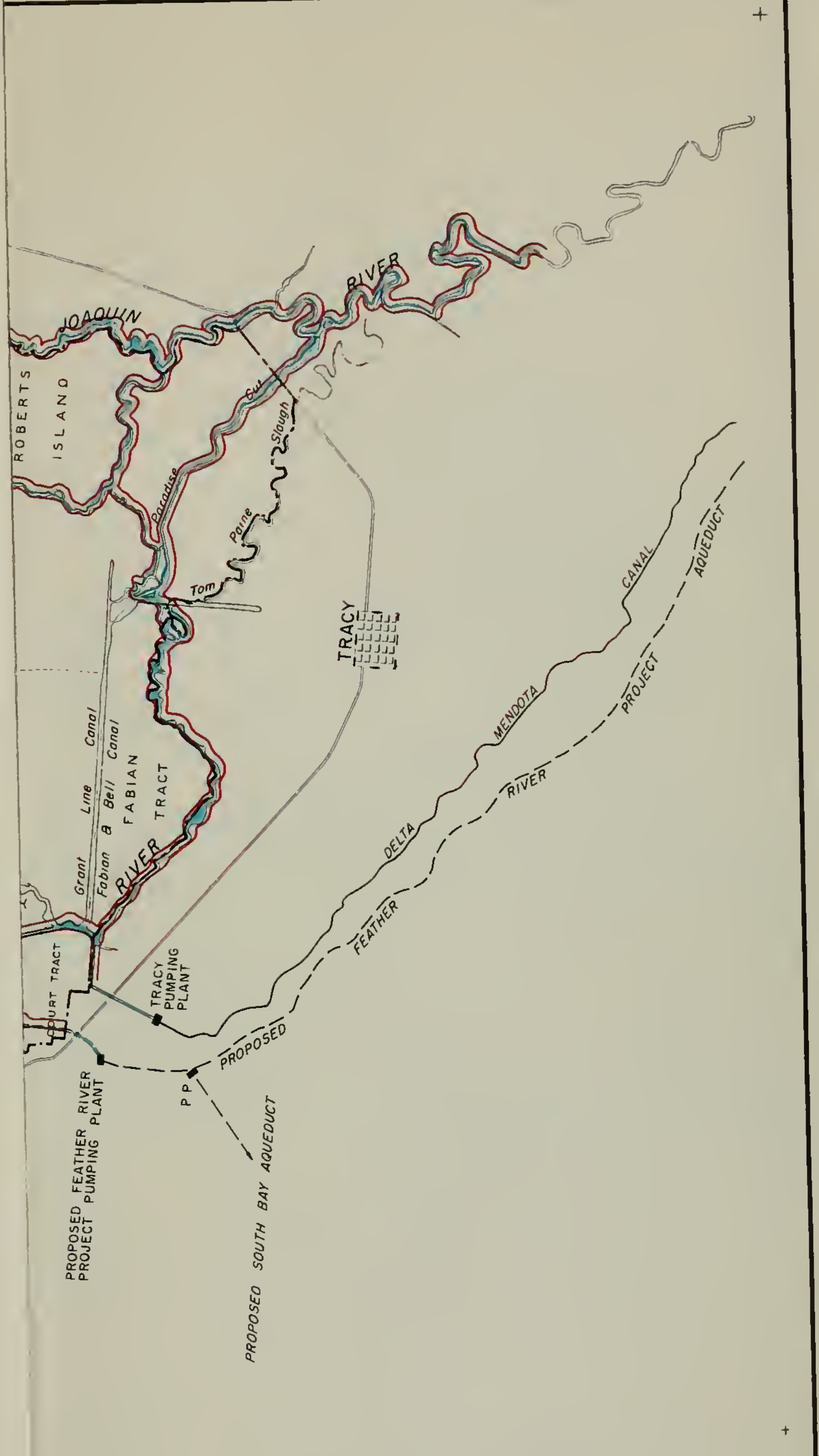
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

LAYOUT OF PRINCIPAL STRUCTURES
CHIPPS ISLAND BARRIER PLANS
MARCH 1957

SCALE AS SHOWN

PLATE 7



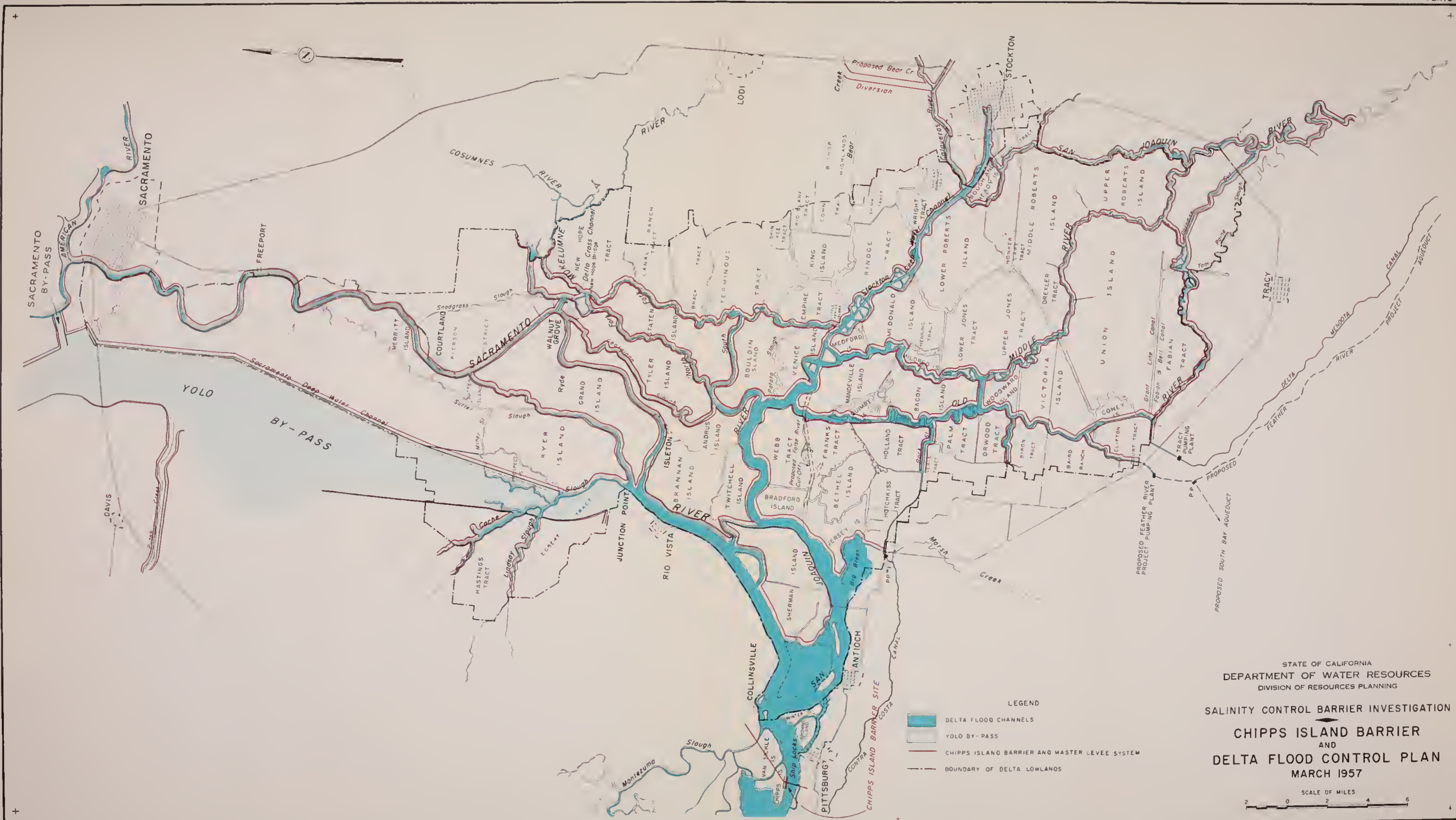
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

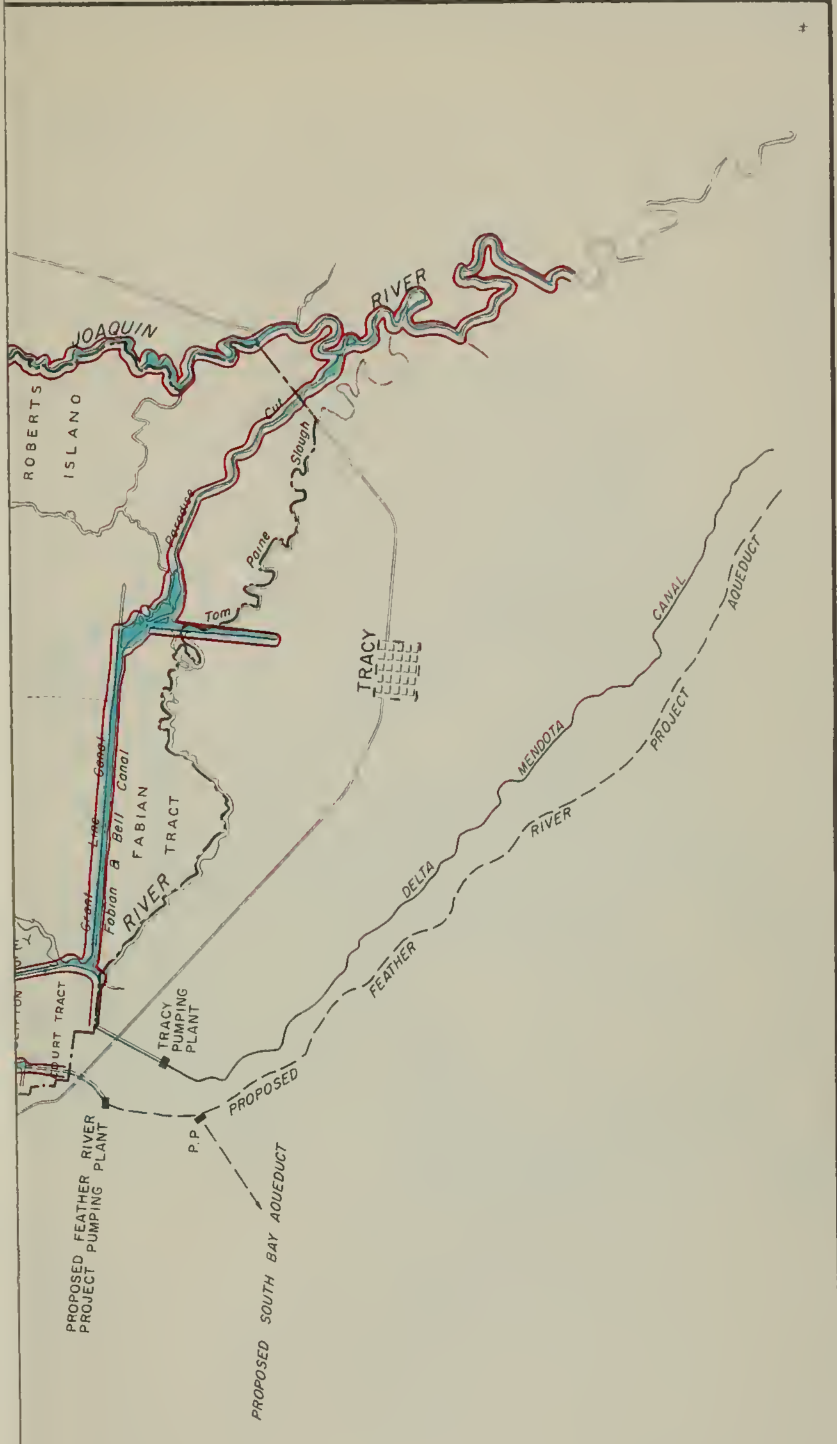
SALINITY CONTROL BARRIER INVESTIGATION

CHIPPS ISLAND BARRIER
AND
DELTA FLOOD CONTROL PLAN
MARCH 1957

SCALE OF MILES
2 0 2 4 6

51344-C


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SALINITY CONTROL BARRIER INVESTIGATION
CHIPPS ISLAND BARRIER
AND
DELTA FLOOD CONTROL PLAN
MARCH 1957
SCALE OF MILES
2 0 2 4 6
LEGEND
DELTA FLOOD CHANNELS
YOLO BY-PASS
CHIPPS ISLAND BARRIER AND MASTER LEVEE SYSTEM
BOUNDARY OF DELTA LOWLANDS
SACRAMENTO
STOCKTON
LODI
TRACY
ANTIOCH
PITTSBURG
COLLINSVILLE
RIO VISTA
ISLETON
WALNUT GROVE
COURTLAND
FREEPORT
DAVIS
YOLO BY-PASS
SACRAMENTO BY-PASS
SACRAMENTO RIVER
SAN JOAQUIN RIVER
MOKELUMNE RIVER
COSUMNES RIVER
AMERICAN RIVER
MIDDLE RIVER
OLD RIVER
Sacramento Deep Water Channel
Stockton Deep Water Channel
CHIPPS ISLAND BARRIER SITE
CONTRA COSTA CANAL
DELTA MENDOTA CANAL
FEATHER RIVER PROJECT AQUEDUCT
PROPOSED SOUTH BAY AQUEDUCT
PROPOSED FEATHER RIVER PROJECT PUMPING PLANT
TRACY PUMPING PLANT
Proposed Bear Cr Diversion
Ship Locks
Montezuma Slough
Marsh Creek
UNION ISLAND
ROBERTS ISLAND
VICTORIA ISLAND
SHERMAN ISLAND
TWITCHELL ISLAND
BRANNAN ISLAND
GRAND ISLAND
RYER ISLAND
TYLER ISLAND
STATEN ISLAND
BOULDIN ISLAND
VENICE ISLAND
MANDEVILLE ISLAND
BACON ISLAND
WEBB TRACT
FRANKS TRACT
BETHEL ISLAND
HOLLAND TRACT
PALM TRACT
ORWOOD TRACT
BYRON TRACT
HASTINGS TRACT
TERMINOUS TRACT
RINDGE TRACT
KING ISLAND
EMPIRE TRACT
MCDONALD ISLAND
LOWER JONES TRACT
UPPER JONES TRACT
DREXLER TRACT
FABIAN TRACT
BRADFORD ISLAND
JERSEY IS.
HOTCHKISS TRACT
MERRITT ISLAND
ANDRUS ISLAND
JUNCTION POINT



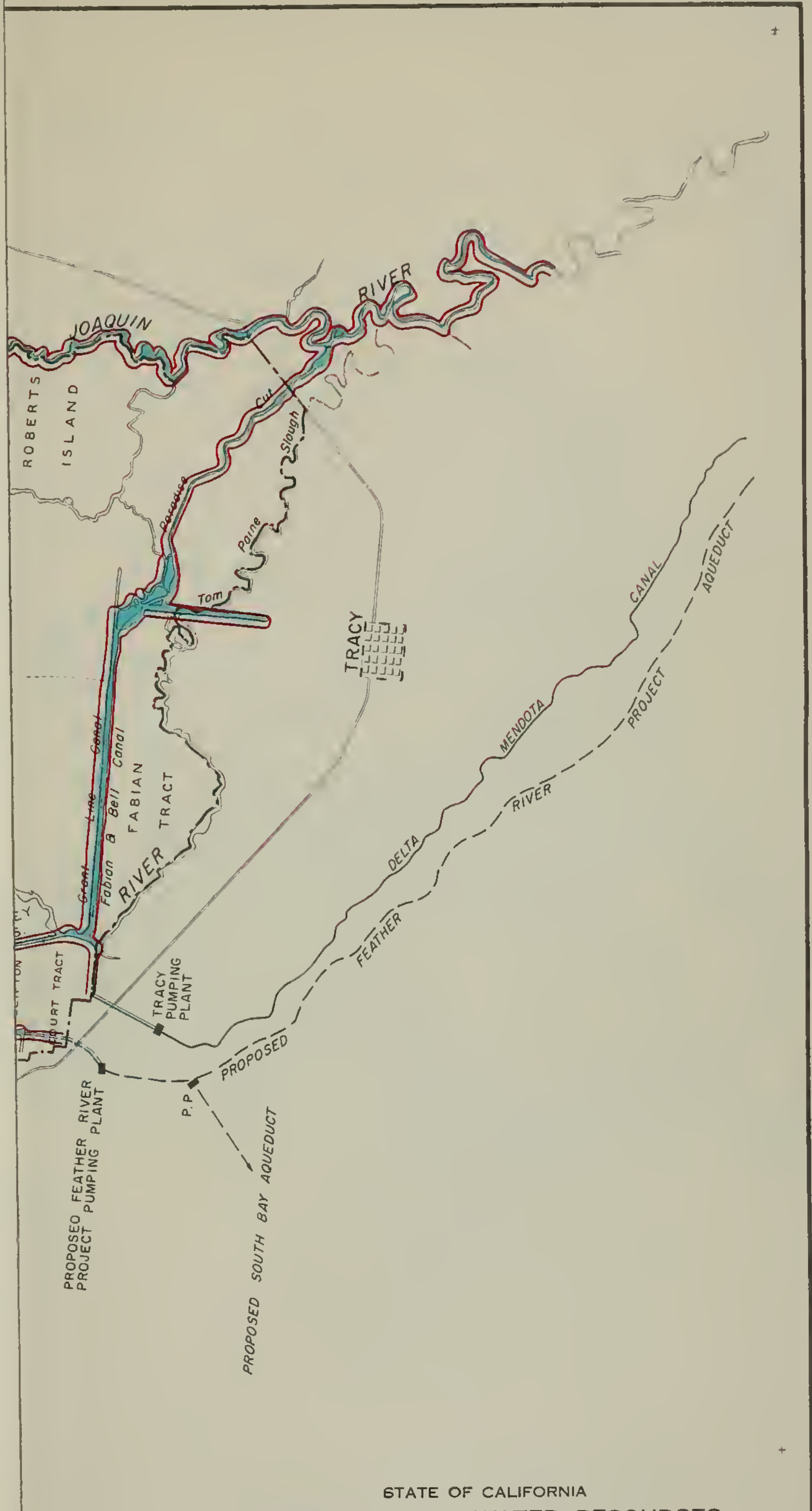
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

MODIFIED CHIPPS ISLAND BARRIER AND DELTA FLOOD CONTROL PLAN

MARCH 1957

SCALE OF MILES
2 0 2 4 6



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

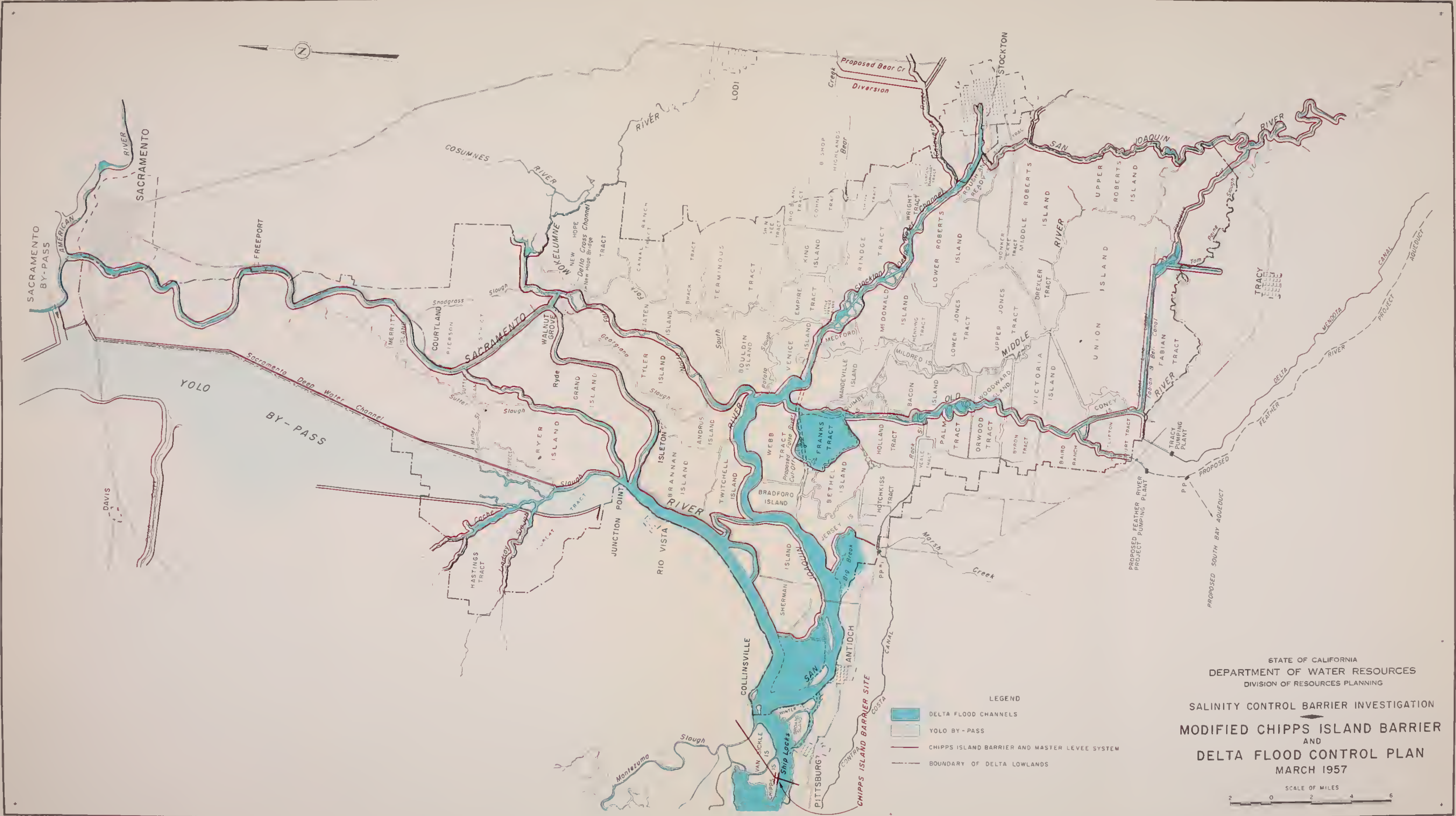
SALINITY CONTROL BARRIER INVESTIGATION

MODIFIED CHIPPS ISLAND BARRIER AND DELTA FLOOD CONTROL PLAN

MARCH 1957

SCALE OF MILES

2 0 2 4 6

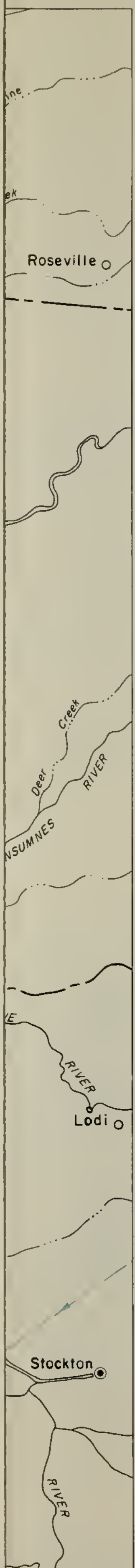


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

MODIFIED CHIPPS ISLAND BARRIER AND DELTA FLOOD CONTROL PLAN

MARCH 1957



LEGEND

PRIMARY WATER SERVICE NORTH BAY AQUEDUCT

SUPPLEMENTAL WATER SERVICE NORTH BAY AQUEDUCT

PRIMARY WATER SERVICE RUSSIAN RIVER PROJECTS

RECLAMATION DISTRICT

IRRIGATION DISTRICT

WATER ASSOCIATION

WATER DISTRICT

UTILITY DISTRICT

EXISTING WATER CONSERVATION WORKS

PROPOSED WATER CONSERVATION WORKS

BOUNDARY OF HYDROGRAPHIC AREA

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

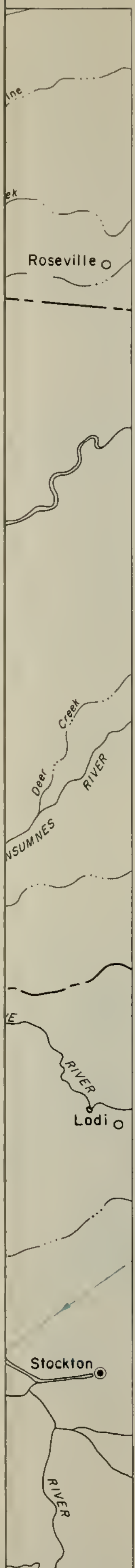
SAN FRANCISCO BAY COUNTIES WATER PLAN

MARCH 1957

SHEET 1 OF 2 SHEETS

SCALE OF MILES

4 0 4 8 12



LEGEND

- PRIMARY WATER SERVICE NORTH BAY AQUEDUCT
- SUPPLEMENTAL WATER SERVICE NORTH BAY AQUEDUCT
- PRIMARY WATER SERVICE RUSSIAN RIVER PROJECTS
- RECLAMATION DISTRICT
- IRRIGATION DISTRICT
- WATER ASSOCIATION
- WATER DISTRICT
- UTILITY DISTRICT
- EXISTING WATER CONSERVATION WORKS
- PROPOSED WATER CONSERVATION WORKS
- BOUNDARY OF HYDROGRAPHIC AREA

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

SAN FRANCISCO BAY COUNTIES WATER PLAN

MARCH 1957

SHEET 1 OF 2 SHEETS

SCALE OF MILES

4 0 4 8 12

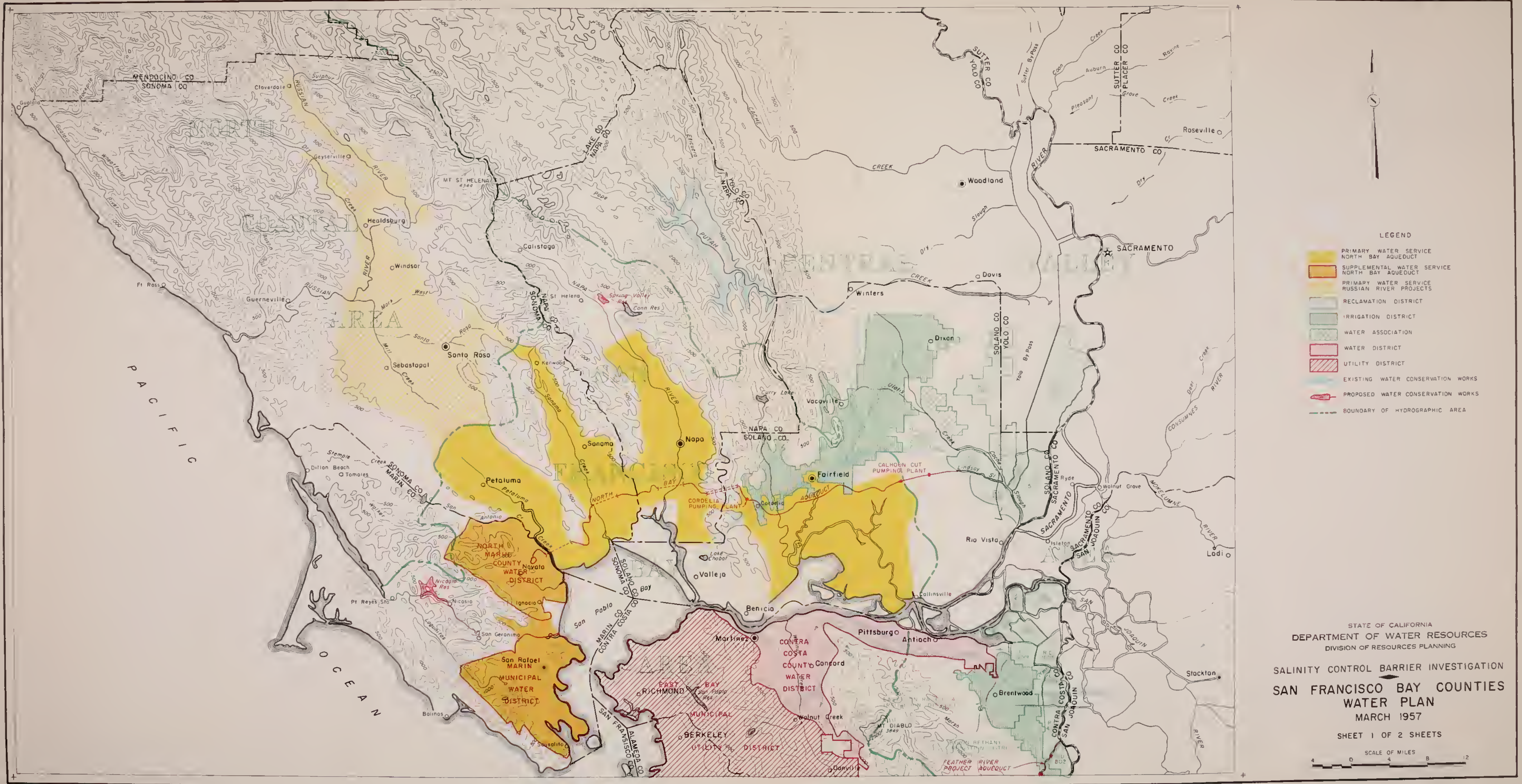
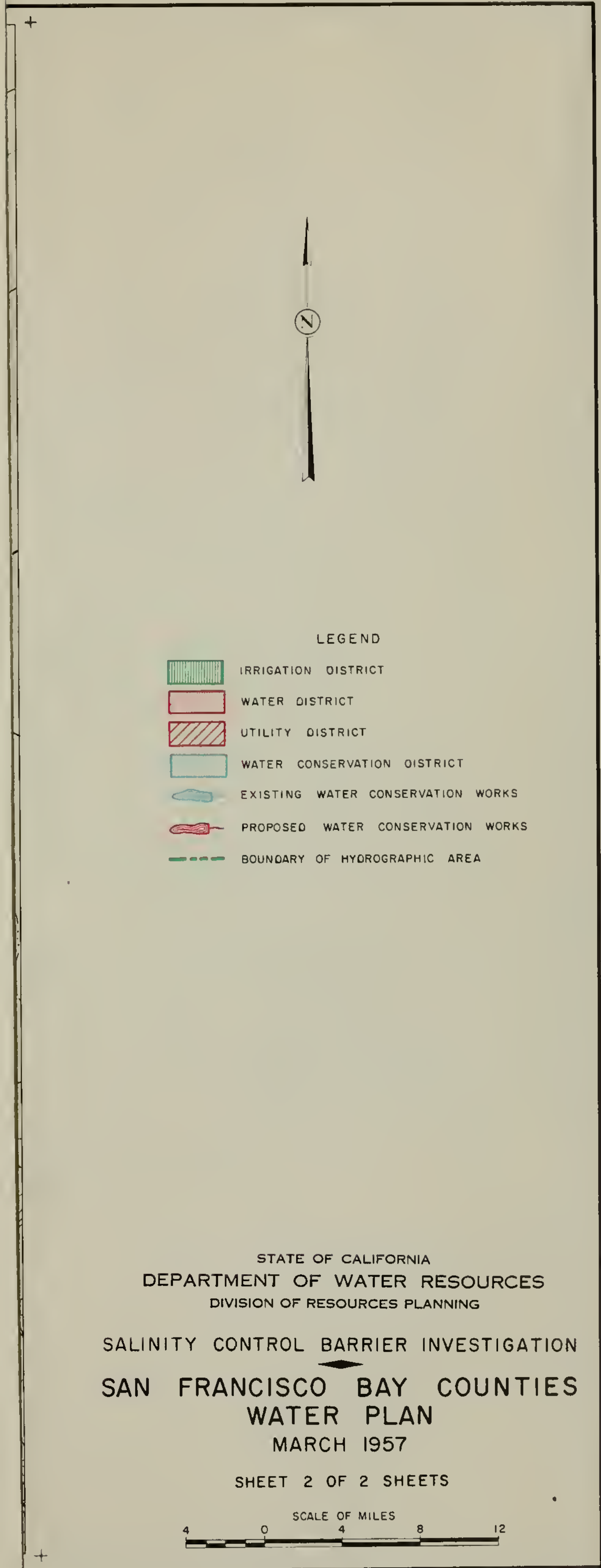

LEGEND
PRIMARY WATER SERVICE NORTH BAY AQUEDUCT
SUPPLEMENTAL WATER SERVICE NORTH BAY AQUEDUCT
PRIMARY WATER SERVICE RUSSIAN RIVER PROJECTS
RECLAMATION DISTRICT
IRRIGATION DISTRICT
WATER ASSOCIATION
WATER DISTRICT
UTILITY DISTRICT
EXISTING WATER CONSERVATION WORKS
PROPOSED WATER CONSERVATION WORKS
BOUNDARY OF HYDROGRAPHIC AREA
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SALINITY CONTROL BARRIER INVESTIGATION
SAN FRANCISCO BAY COUNTIES WATER PLAN
MARCH 1957
SHEET 1 OF 2 SHEETS
SCALE OF MILES
4 0 4 8 12
PACIFIC OCEAN
NORTH COASTAL AREA
SAN FRANCISCO BAY AREA
CENTRAL VALLEY AREA
MENDOCINO CO
SONOMA CO
LAKE CO
NAPA CO
YOLO CO
SUTTER CO
PLACER CO
SACRAMENTO CO
SOLANO CO
MARIN CO
CONTRA COSTA CO
ALAMEDA CO
SAN JOAQUIN CO
SAN FRANCISCO
Gualala
Cloverdale
Geyserville
Healdsburg
Windsor
Ft Ross
Guerneville
Santa Rosa
Sebastopol
MT ST HELENA 4344
Calistoga
St Helena
Kenwood
Sonoma
Napa
Petaluma
Dillon Beach
Tomales
Novato
Ignacio
Nicasio
Nicasio Res
Pt Reyes Sta
San Geronimo
San Rafael
Bolinas
Sausalito
Vallejo
Benicia
Martinez
Concord
Pittsburg
Antioch
Brentwood
Walnut Creek
Danville
MT DIABLO 3849
RICHMOND
BERKELEY
Fairfield
Cordelia
Vacaville
Dixon
Winters
Davis
Woodland
SACRAMENTO
Roseville
Rio Vista
Isleton
Collinsville
Ryde
Walnut Grove
Lodi
Stockton
NORTH BAY AQUEDUCT
CORDELIA PUMPING PLANT
CALHOUN CUT PUMPING PLANT
FEATHER RIVER PROJECT AQUEDUCT
NORTH MARIN COUNTY WATER DISTRICT
MARIN MUNICIPAL WATER DISTRICT
EAST BAY MUNICIPAL UTILITY DISTRICT
CONTRA COSTA COUNTY WATER DISTRICT
RUSSIAN RIVER
NAPA RIVER
SACRAMENTO RIVER
SAN JOAQUIN RIVER
San Pablo Bay
Spring Valley Res
Conn Res
Curry Lake
Lake Chabot
San Pablo Res

PLATE 9

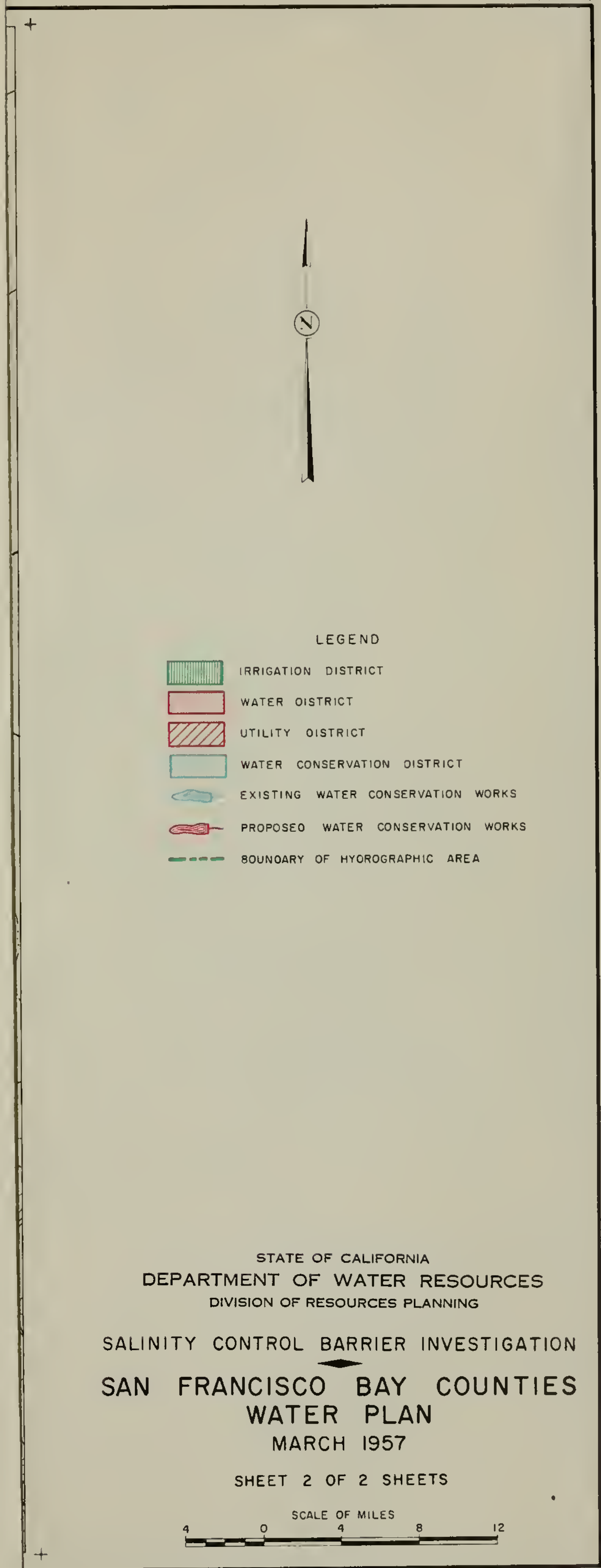


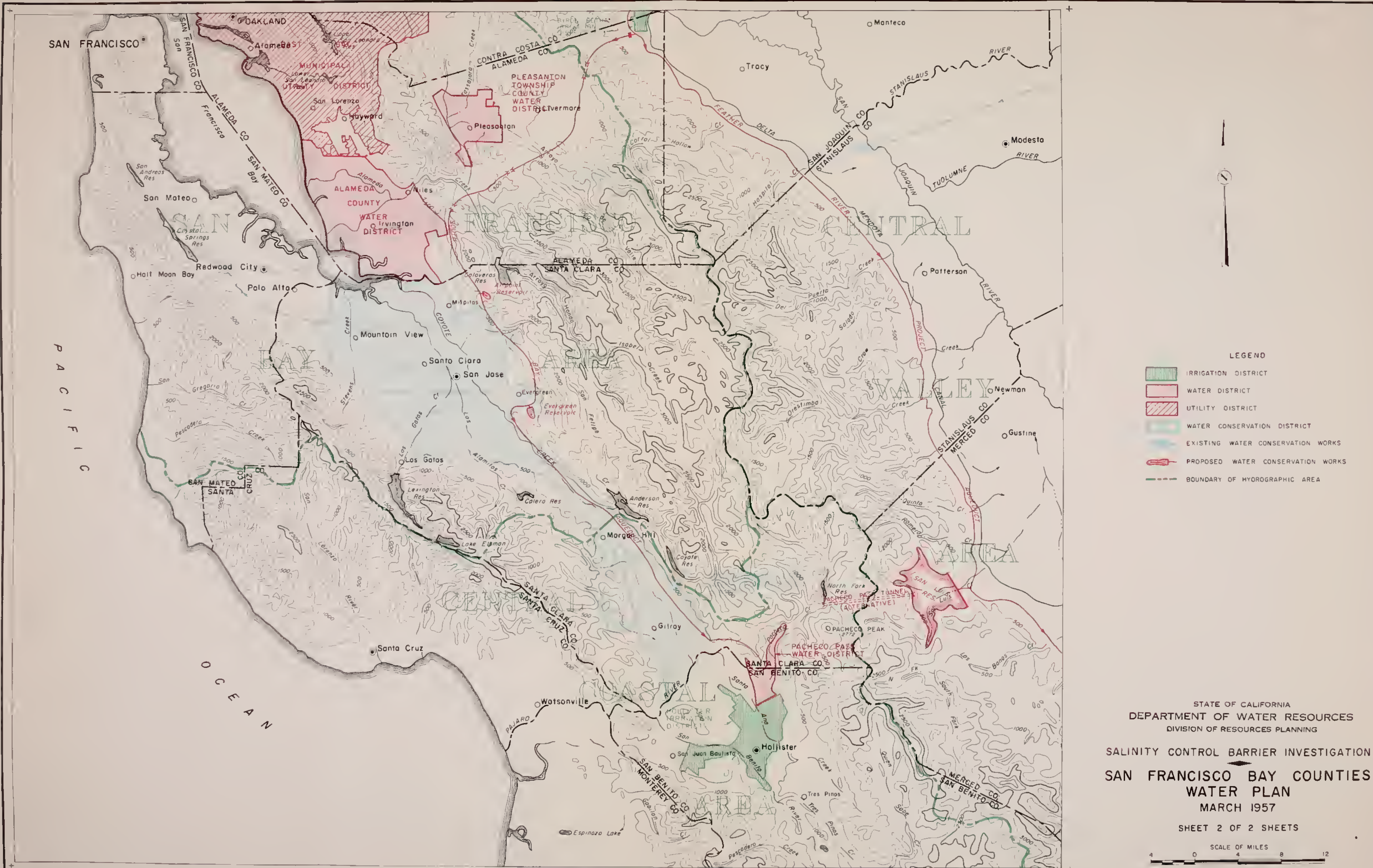
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

SAN FRANCISCO BAY COUNTIES
WATER PLAN
MARCH 1957

SHEET 2 OF 2 SHEETS


LEGEND
IRRIGATION DISTRICT
WATER DISTRICT
UTILITY DISTRICT
WATER CONSERVATION DISTRICT
EXISTING WATER CONSERVATION WORKS
PROPOSED WATER CONSERVATION WORKS
BOUNDARY OF HYDROGRAPHIC AREA
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
SALINITY CONTROL BARRIER INVESTIGATION
SAN FRANCISCO BAY COUNTIES
WATER PLAN
MARCH 1957
SHEET 2 OF 2 SHEETS
SCALE OF MILES
4 0 4 8 12



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

SALINITY CONTROL BARRIER INVESTIGATION

SAN FRANCISCO BAY COUNTIES WATER PLAN

MARCH 1957

SHEET 2 OF 2 SHEETS